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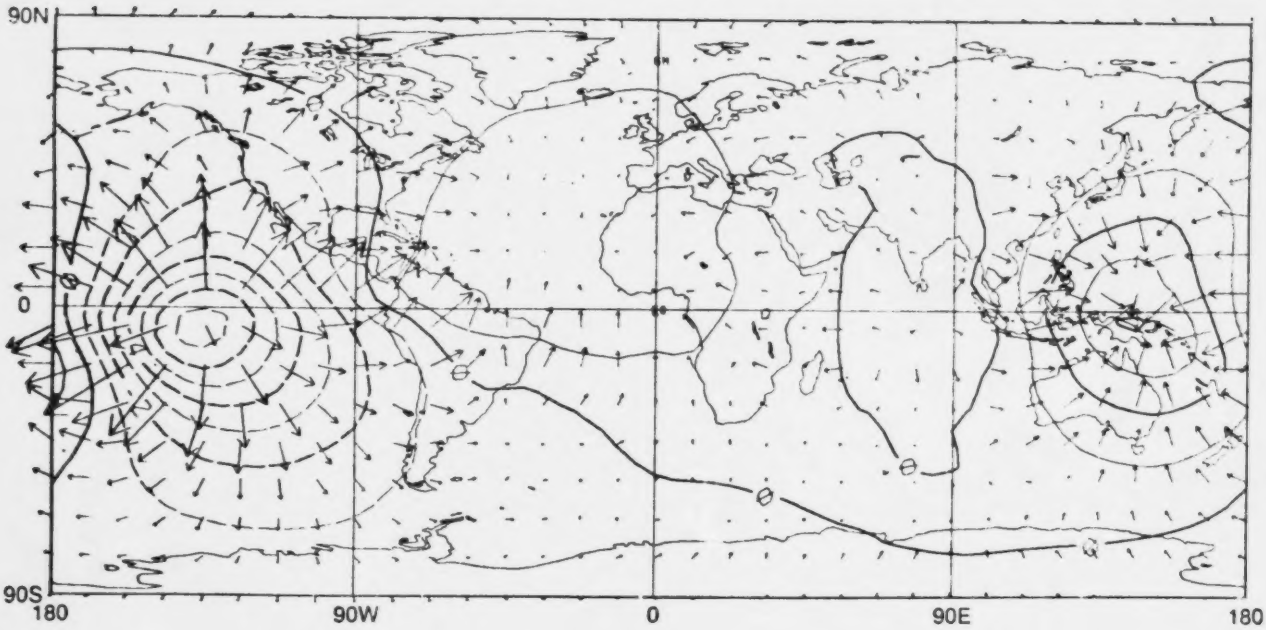
1984 Annual Report

National Climate Program



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The cover illustration is significant in at least three respects: (1) it demonstrates the importance of processes in the equatorial Pacific Ocean in affecting global weather; (2) it shows advances in understanding of very extensive climate processes which are likely to lead to credible monthly, seasonal and interannual climate forecasts; and (3) it represents the benefits to the U.S. National Climate Program of international scientific collaboration--over twenty nations have joined to study the El Nino--Southern Oscillation phenomena. The figure (courtesy of G.J. Boer, Canadian Climate Center) shows the changes in atmospheric energy for the December-February season as simulated by the Centre's general circulation model in response to the anomalous tropical sea surface temperatures of the 1982-83 El Nino. The result indicates a marked increase in the export of energy from the tropical Eastern Pacific while there is a decrease in the usual export of energy in the Western Pacific.

Single copies available from

National Climate Program Office
National Oceanic & Atmospheric Administration
11400 Rockville Pike, Room #108
Rockville, MD 20852
(301) 443-8981

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NATIONAL CLIMATE PROGRAM
ANNUAL REPORT
1984

January 1986

PARTICIPATING AGENCIES:

Department of Agriculture
Department of Commerce
Department of Defense
Department of Energy
Department of Health and Human Services
Department of Housing and Urban Development
Department of the Interior
Department of Justice
Department of State
Department of Transportation
Department of the Treasury
Agency for International Development
Council on Environmental Quality
Environmental Protection Agency
Federal Emergency Management Agency
National Aeronautics and Space Administration
National Science Foundation

Compiled by the National Climate Program Office

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
11400 Rockville Pike
Rockville, Maryland 20852
(301) 443–8981

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THE SECRETARY OF COMMERCE
Washington, D.C. 20230

JAN 13 1986

The President
Honorable John C. Danforth
Honorable Don Fuqua

Sirs:

I am pleased to submit the annual report on the activities of the National Climate Program, for fiscal year 1984, in compliance with Section 7 of the National Climate Program Act of 1978 (15 U.S.C. §2906)

Sincerely,

Malcolm Baldrige

Secretary of Commerce

Enclosure

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ACRONYMS

AFOS	Automation of Field Operations and Services
AGNET	A nationwide agricultural information service network
AID	Agency for International Development
AISC	Assessment and Information Services Center
AVHRR	Advanced very high resolution radiometer
AWDN	Automated Weather Data Network
CAC	Climate Analysis Center
CAMS	Climate Anomaly Monitoring System
CARES	Comprehensive Area Rainfall Estimation System
CLICOM	Climate Computer System
CLIMOD	Climate Information for Management and Operational Decisions
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOS	Department of State
ENSO	El Nino and Southern Oscillation
EPA	Environmental Protection Agency
EPOCS	Equatorial Pacific Ocean Climate Studies
ERBE	Earth Radiation Budget Experiment
ERL	Environmental Research Laboratories
FAA	Federal Aviation Administration
FAO	Food and Agriculture Organization (UN)
FIRE	First ISCCP Regional Experiment
GCM	Global circulation model
GFDL	Geophysical Fluid Dynamics Laboratory
GLAS	Goddard Laboratory of Atmospheric Sciences
GMS	Geostationary meteorological satellite
GOES	Geostationary operational environmental satellite
GPS	Global Positioning System
GSFC	Goddard Space Flight Center
GTS	Global Telecommunication System
HCS	Historical climatology series
INSAT	Indian satellite
ICRCCM	Intercomparison of radiation code in climate models
ICSU	International Council of Scientific Unions
ISCCP	International Satellite Cloud Climatology Project
ISLSCP	International Satellite Land-Surface Climatology Project
LDC	Lesser developed country
METEOSAT	European meteorological satellite
MLEBM	Multilayer energy balance model

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NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NCP	National Climate Program
NCPO	National Climate Program Office
NEDRES	National Environmental Data Referral Service
NESDIS	National Environmental Satellite, Data, and Information Service
Nimbus	Meteorological satellite system
NMC	National Meteorological Center
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRCC	Northeast Regional Climate Center
NSF	National Science Foundation
NWS	National Weather Service
OLR	Outgoing longwave radiation
OMB	Office of Management and Budget
PRC	People's Republic of China
RITS	Radiatively important trace species
SEQUAL	Seasonal response of the Equatorial Atlantic
SRSS	Service Records Retention System
SST	Sea surface temperature
TOGA	Tropical Ocean and Global Atmosphere
UNEP	United Nations Environment Program
UN/ESCAP	United Nations/Economic Commission for Asia and the Pacific
USDA	U.S. Department of Agriculture
USSR	Union of Soviet Socialist Republics
VLBI	Very long baseline interferometry
VOS	Volunteer observing ships
WCDP	World Climate Data Program
WCP	World Climate Program
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WUE	Water-use efficiency
WWCB	Weekly Weather and Crop Bulletin
XBT	Expendable bathythermograph

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OVERVIEW

Discussion of national and international climate policy issues and steady progress in scientific understanding dominated the activities of the climate program in 1984.

Climate modeling studies were the basis for proposing the hypothesis of "nuclear winter"—that smoke and dust produced during nuclear fires, once lofted high in the atmosphere, would block much of the sunlight reaching the earth's surface. A prolonged period of sub- or near-freezing temperatures might occur over much of the northern hemisphere following a large-scale nuclear war. Because of large uncertainties in estimates of smoke inputs and the present level of sophistication in climate models, the hypothesis of nuclear winter cannot be accepted or rejected at this time.

This hypothesis and its policy implications were the subject of several congressional hearings and interagency reviews in 1984. The National Climate Program Office (NCPO) was asked by presidential science advisor George Keyworth II to coordinate the preparation of an interagency research plan designed to address the major uncertainties in the hypothesis. The NCPO, working with scientists in various agencies and with university scientists, developed a research strategy that is now the basis for an interagency program being coordinated by the Office of Science Technology and Policy (OSTP).

Continued drought in Africa and the continued trend of extreme seasonal weather underscore the need to better understand and predict climate variations.

From 1975-76 to 1982-83 there has been an uncharacteristic spell of abnormal winters in the United States, and the winter of 1983-84 continued this pattern. Three winters during this 8-year period were much warmer than normal and three consecutive winters (1976-77 through 1978-79) were much colder than normal (Karl, Livezey, and Epstein, 1984). The frequency of these weather anomalies was greater than would be expected from the historical record between 1895 and 1983.

Increases in precipitation in the Great Salt Lake region that have reached record-breaking highs underscore the social impact of climate change. The State of Utah foresees construction costs of near $1 billion to prevent flooding if the Great Salt Lake continues its unprecedented rate of rise. The causes of the anomalies and trends are unknown. Continued analysis of historic data, along with modeling and diagnostics studies, may explain more of the possible causes. What is known is that these climate variations and possible changes markedly affect our global economic and social well-being.

Over the past year, steady progress has been made in understanding the large-scale circulation of the atmosphere and the interaction of the atmosphere and oceans. The winter of 1982-1983 witnessed the most outstanding example of an El Nino event, i.e., large persistent sea surface temperature (SST) anomalies over the equatorial Pacific and related circulation anomalies over many parts of the earth. Several climate modeling groups around the world have conducted sensitivity experiments for these observed SST anomalies using their respective general circulation climate models. These experiments and their consistent results are leading to increased optimism that forecast skill can be improved on monthly and seasonal time scales. Since the influence of tropical SST anomalies on atmospheric circulation holds major promise for predicting short-term climate, it is important to understand the origin and development of these anomalies. U.S and international scientists have begun preparations for a 10-year research effort on the interannual variability of the tropical oceans and global atmosphere (TOGA). While the international TOGA program does not begin until January 1985, the U.S. TOGA observing system of meterological stations, tidal gauges, current meters, and subsurface temperature moorings began operating in 1984. The data collected by this program will become essential to new modeling and prediction studies for events like the El Nino.

A third experimental Climate Forecast Center has been established at the University of Washington to further development of predictive models based on TOGA-related studies. The experimental climate forecast centers work closely with the official forecast center of the National Weather Service to develop and test new forecasting models. Where new models appear promising, the NWS will incorporate them into their operational forecasting.

A major goal of the NCP is to improve the availability of climate information for government and private sector use. A climate anomaly monitoring system (CAMS) has been implemented as a basic operational tool for climate monitoring. The routine generation of CAMS products is the culmination of a long-term effort to establish an objective system for real-time identification and tracking of global surface climate anomalies.

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At the end of 1983 both the Environmental Protection Agency and the National Academy of Sciences issued separate reports predicting a long-term climatic warming associated with increasing CO_2. However, while general circulation models project an average global warming due to increased CO_2 levels, no direct climate change due to increasing CO_2 has been confirmed. Although the reports differed somewhat in the timing and extent of the warming effect, both emphasized the impacts that trace gases have on climate. The most comprehensive study to date on the effects of other radiatively important trace gases on climate now indicates that within 50 years, the combined warming effect of other trace gases will be comparable to and perhaps exceed by a significant amount the effect of CO_2. NSF, NOAA, and DOE have shifted research to give greater emphasis to other trace gases besides CO_2 which have a potentially serious effect on climate. Systematic monitoring of methane has begun and plans for expanding monitoring and research programs have been organized by NOAA for implementation in 1985.

Finally, the DOE is preparing major summaries of CO_2 research for publication in 1985. These "state of the art" reports will contain the most current and comprehensive statement possible of the knowns and uncertainties of the CO_2 problem, on which more than $100 million has been spent since 1978.

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I. Introduction

The National Climate Program Act (P.L. 95-367) was passed by Congress in 1978 to promote a national effort to better understand climate variation and its impact on society. Now in its seventh year, this program has made considerable progress in meeting the goals mandated by the Act.

In compliance with this Act, this annual report for 1984 describes the year's major activities, including a summary of progress toward the objectives and milestones of the program. These milestones are described in a 5-year plan for the program, a report also mandated by the Act.

There has been rapid progress in the study of climate over the past 5 years. Several new programs are now under way which were not imagined at the time the original 5-year plan was drafted in 1978. As a consequence, an interim plan covering the fiscal years 1984-1986 has been prepared to better reflect priorities and new milestones of the national program. A second 5-year plan is being developed for the period FY 1986-1990.

The basic structure of the National Climate Program (NCP) contains three major components:

1. Providing climate products and services
2. Responding to climate impacts and policy
3. Climate research and prediction

Information on the activities described in this report was supplied by the federal agencies involved. The persons listed below can provide more details on specific areas.

Agency for International Development (AID)
Jack Sullivan ..... (703) 235-2559
Department of Agriculture (USDA)
Norton D. Strommen ..... (202) 447-9805
Department of Commerce (NOAA)
Orville Scribner ..... (301) 443-8415
Department of Defense (DOD)
Captain Edward J. Harrison, Jr. ..... (202) 695-9604
Department of Energy (DOE)
Frederick Koomanoff ..... (301) 353-3281
Department of Interior (DOI)
Richard Z. Poore ..... (703) 860-7289
Department of State (DOS)
William Long ..... (202) 632-2418
National Aeronautics and Space Administration (NASA)
Robert A. Schiffer ..... (202) 435-1680
National Science Foundation (NSF)
Thomas Crowley ..... (202) 357-9892

Overall information on the program may be obtained from the office of Alan D. Hecht, Director, National Climate Program Office, National Oceanic and Atmospheric Administration (301) 443-8646.

This year's report was edited by Ruth B. Haas.

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II. Summary of Significant Achievements

PROVIDING CLIMATE PRODUCTS AND SERVICES

HIGHLIGHTS

- *North American Climate Data Catalog* published
- Climate anomaly monitoring system and information services implemented
- Agricultural and energy-related weather information improved
- Comprehensive Area Rainfall Estimation System (CARES) established
- National Climate Data Center (NCDC)/state climatologist exchange program begins
- Climate Information for Management and Operational Decisions System (CLIMOD) established at Cornell University
- Illinois Climate Center Data System established
- Automated weather network in Midwest expanded

North American Data Catalog

The Assessment and Information Service Center (AISC) for NOAA prepared the *North American Climate Data Catalog—Part 1*, the first publication derived from the data base of the National Environmental Data Referral Service (NEDRES). Publication of this catalog is a step toward a national inventory of climatic data, as called for by the National Climate Program's Five-Year Plan. The catalog contains descriptions of 770 climate data files available from organizations in the United States and Canada and from individuals and state organizations in the Northeast. The entries for the northeast region resulted from a survey by the Northeastern Regional Climate Coordination Center, located at Cornell University, which conducted an inventory of data holdings in New England and the Mid-Atlantic states. A southern regional climate data inventory is now in progress for the states of Virginia, North Carolina, Alabama, Georgia, Florida, Mississippi, South Carolina, Tennessee, Texas, Oklahoma, and Arkansas. These inventories will form the basis for the second volume of the *North American Climate Data Catalog*, to be published in 1985.

Climate Anomaly Monitoring System

The NOAA/Climate Analysis Center (CAC) has implemented the Climate Anomaly Monitoring System (CAMS) as a basic operational tool for climate monitoring. The routine generation of CAMS products is the culmination of a long-term effort to establish an objective system for real-time identification and tracking of global surface climate anomalies (figure 1). New products were developed that characterized the intensity and impact of global surface temperature and precipitation anomalies in probabilistic terms. Also, a global precipitation anomaly classification for drought assessment was developed by modifying a previously derived index, so that CAMS data could be used. Global maps depicting dry and wet areas (5 classes) based on this method, as well as maps that display standardized temperature anomalies and quantities of precipitation, are now being produced routinely each month.

Current Climate Information Services

CAC has also developed summary files of weekly, monthly, seasonal, and annual climate data from its Climate Assessment Data Base for use in climate anomaly assessments. These files permit access to summaries of current global station precipitation and temperature data over intervals from 1 to 52 weeks. Efforts are being directed toward identifying potential new sources of detailed global and national climatological data to improve climate analysis and assessment in data-sparse areas.

The CAC has enlarged its computer-based data and information system. Currently, an average of 120 users per week are using this request-reply dial-up system. New products available on the system include: foreign weather and climate summaries, foreign agricultural summaries, 7-day maximum and minimum temperature forecasts for 123 U.S. cities, projected monthly and seasonal population-weighted state, regional and national degree-day values, regional and national temperature departure indices, and accumulated growing degree-day values. Weekly and monthly summarized global surface station data and selected gridded monthly ocean analyses are now quickly available to users.

As another facet of its user information services, the CAC routinely prepares and issues weekly and monthly climate bulletins that depict significant temperature and precipitation anomalies. The *Monthly Climate Bulletin* (a new product in 1984) is now distributed internationally under the auspices of the World Climate Program of the World

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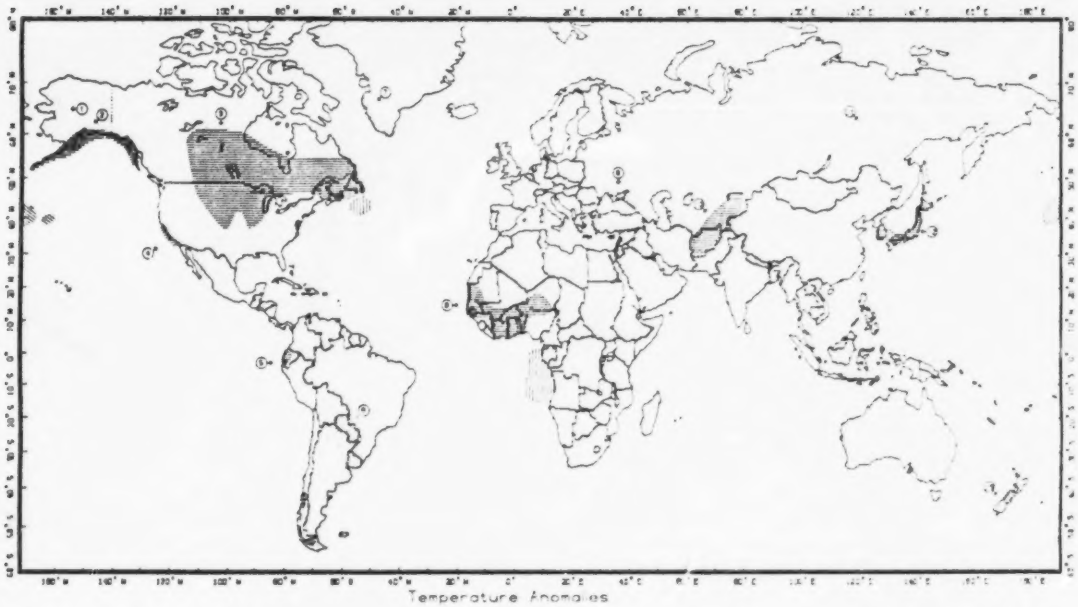

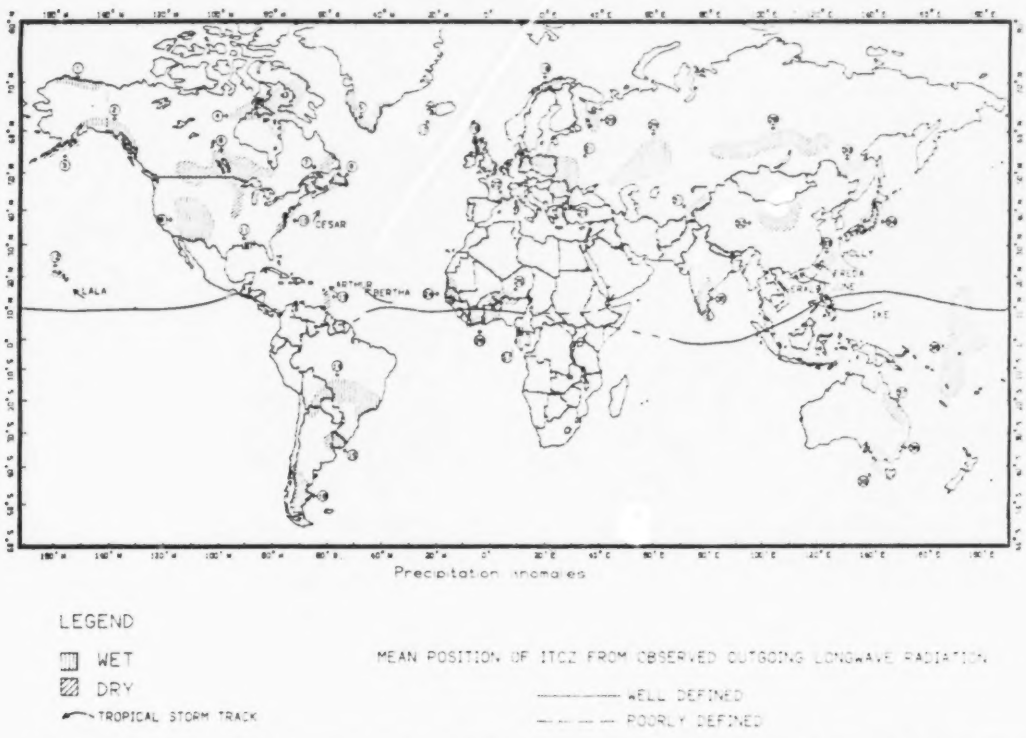

Figure 1.—Significant global temperature and precipitation anomalies, identified by CAC/NOAA, for August 1984. These anomaly reports are published monthly.

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Meteorological Organization. Seasonal and longer term climate assessments are being produced experimentally and their issuance is planned during 1985.

Climate and Energy

The CAC request-reply communications system has proven to be an excellent facility to supply energy users with timely data and products. New energy products include monthly and seasonal population-weighted state, regional, and national heating degree-day values (based on CAC's 30-and 90-day temperature outlooks) and automated daily maximum and minimum 7-day temperature forecasts for 123 U.S. cities

Climate and Agriculture

NESDIS's National Climatic Data Center completed new climatological summaries for the agricultural community. Available for nearly 1,900 sites, the new *Climatography of the United States No. 20* summarizes data for the period 1951-1980. Details include temperature and precipitation means and extremes, heating and cooling requirements, growing degree-days, and precipitation and freeze date probabilities.

The *Weekly Weather and Crop Bulletin* (WWCB), a joint effort of NOAA and USDA, has been modified to better serve users. Two automated products were added: a growing degree-days map and a monthly weather data table for selected cities in the United States. Charts that show percent of field capacity to hold moisture were added to the Palmer index series of products. New graphic products that depict soil temperature, pan evaporation, and snow cover have also been developed.

Improved procedures for identification and description of long-term drought have also been developed at the Climate Analysis Center. Weekly Palmer drought and crop moisture indices are being calculated year round and disseminated via automation of field operations and services (AFOS). CAC's high density precipitation data file now includes data from U.S. river forecast centers and the climate assessment data base. The NCDC also has a national high density precipitation data file, which includes over 8,500 stations. The CAC prepares rainfall totals that are now being averaged over many U.S. climate divisions. Probability projections of the Palmer drought index, 3 months in advance, are being computed monthly and are now available on CAC's microcomputer. Near real-time monthly precipitation deficiency indices for U.S. climate divisions are being computed and are available on CAC's microcomputer. Time series charts showing the cumulative precipitation for the previous 40 weeks (compared with the cumulative normal amount) were developed for stations with complete sets of weekly precipitation data and are used in special analyses of precipitation-deficient regions.

Comprehensive Areal Rainfall Estimation System (CARES)

NOAA's Assessment and Information Services Center developed the Comprehensive Areal Rainfall Estimation System (CARES), a data base applicable on a VAX minicomputer. CARES stores daily summaries of precipitation and temperature data for about 1,500 WMO stations in the developing countries. Also stored are the weekly and monthly precipitation averages for agroclimatic areas. CARES provides the analyst with a means for searching and retrieving data for specific conditions, time periods, and geographic areas.

NCDC-State Climatologist Exchange Program Begins

NCDC announced the beginning of an exchange program with state climatologists which allows them to visit and work at NCDC for 2 to 6 weeks on topics that benefit both national and state climate programs. During 1984, participants in the exchange program concentrated on station histories, digitizing and quality control of hourly precipitation data for Alaska (none existed prior to this effort), and joint research projects involving the study of time of observation bias. Applications for the NCDC/State Climatologist Exchange Program are due at the end of each year to Director, NCDC, Asheville, NC 28801.

Federal/State Climate Program: CLIMOD

The Northeast Regional Climate Center (NRCC) was established in September 1983 to coordinate climate research and services in twelve states from Maine to Pennsylvania. The NRCC is supported by NCPO, federal (USDA) regional research funds, and by the states. The center is engaged in cooperative research with state climatologists in Massachusetts, New Hampshire, and New Jersey. In states with no state climatologists or with limited resources for the state climatologists, NRCC performs the role of state climatologist or acts as the resource base. The center has organized a computer system, CLIMOD, the Climate Information for Management and Operational Decisions, which was implemented in 1984 and allows the user access to several thousand pages of weather and climate information and data for the region. Included are over 1,700 graphs of daily temperatures and precipitation for the month, which are available by the middle of the following month. This link increases the delivery of useful information to users in the region. Current users of CLIMOD include state climatologists, extension agents, universities, the media, integrated pest management programs, and ski area operators.

The NRCC also publishes a monthly climate summary which is supported by a subscription fee. The user fee helps defray the cost of printing and covers the cost of first class

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mailing. There are now 740 subscriptions, with federal, state, and local governments continuing to be major subscribers to monthly climate summaries of the NRCC.

Illinois Climate Data System

The Illinois Climate Center has developed a system that provides real-time information about many weather parameters and climate-affected conditions throughout the state. Data for the system are derived from cooperative weather observers at thirty-five locations around Illinois, from twenty-two other NWS stations via AFOS, and from the Agricultural Weather Service Center of NWS in Indiana. Each observer uses a touch-tone telephone to quickly digitize and transmit weather observation by telephone line to the climate center in Champaign. Currently, only state agencies are accessing the data information in a user test. The system may eventually be used in other states by the North Central Regional Climate Center in the Midwest. The Illinois Center also has assisted the National Weather Service in developing a system for real-time dissemination of climate data reported by cooperative observers.

Automated Weather Data Network (AWDN) and Regional Drought Assessment

The Automated Weather Data Network, the first of its kind to collect in near-real time the many weather parameters important to agriculture, originally began in Nebraska in 1981 with only four stations. The demonstration project, initially funded by NCPO, has had a rapid increase in the number of stations: there are now twenty-six stations, as shown in figure 2. During its first 3 years the project focused mainly on monitoring agricultural weather data and on applying the data to irrigation scheduling. With the addition of each new station, climate data depicting the normal conditions for each location have been added to the distribution system (AGNET—a nationwide agricultural information service). A survey is under way to determine how AGNET climate information is being used by researchers, extension personnel, state agencies, and people in the private sector. During the past year the AWDN has been expanded to South Dakota, Kansas, Wyoming, and Colorado.

RESPONDING TO CLIMATE IMPACTS AND POLICY

HIGHLIGHTS

- "Nuclear winter" assessed
- Economic impact of 1982-1983 El Nino
- Small Business Administration provides disaster assistance to fishing industry
- International weather anomalies continue
- Technical aid to less developed countries

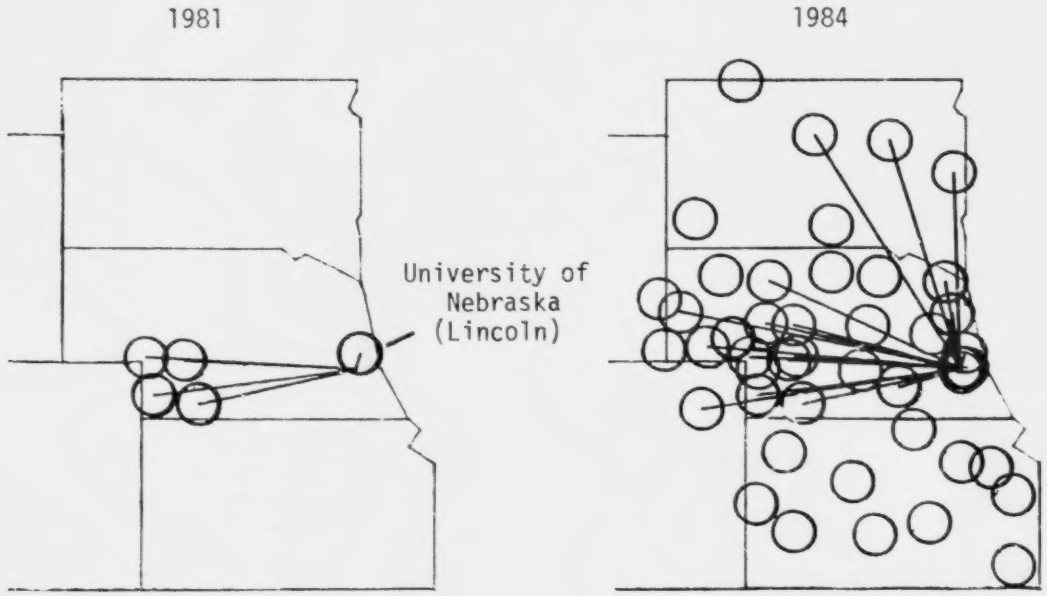

Figure 2.—Growth of the number of automated weather stations used in Nebraska for irrigation scheduling. The initial five stations were funded with federal funds. The network has grown through state support.

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- Climate effect of non-CO_2 trace gases estimated
- New calculations of global carbon budget
- Historic atmospheric CO_2 levels determined from air trapped in ice cores
- CO_2 improves water-use efficiency of plants
- New estimates of sea level rise
- Climate impact of Arctic haze defined

Climate Impact Assessment

"Nuclear Winter" Research and Development of Interagency Plan

The concept of nuclear winter is based on the proposition that large-scale fires and excavated debris produced by many nuclear explosions would create a hemispheric to global blanket of smoke and dust sufficient to greatly reduce the amount of sunlight reaching the earth's surface. A prolonged period of sharply reduced land surface temperature would follow for much of the northern hemisphere.

Crutzen and Birks (1982) were first to attempt to quantify the possible input of smoke into the atmosphere from the burning of forests following a nuclear war.

The first major study of the climatic consequences of both dust and smoke in urban and nonurban areas as a result of nuclear war was published by Turco, Toon, Ackerman, Pollack and Sagan (known as TTAPS) in 1983. The TTAPS study was based on a single one-dimensional climate model which predicted surface land coolings of 20 to 40°C or more for up to many months. Since this first study, several modeling groups led by scientists at the National Center for Atmospheric Research (NCAR), Lawrence Livermore National Laboratory (LLNL), and Los Alamos have improved the climate simulations, which now involve 3-dimensional modeling with interactive smoke and precipitation. Several new climate studies are being done each year. As a result, a clearer picture of the climatic consequences of nuclear war is emerging, while it is apparent that large uncertainties still exist. Recent findings suggest that a volume of smoke of nearly 180 million metric tons is likely to cause a significant lowering of surface temperatures over continental areas. The magnitude of the cooling and its duration may not be large as first proposed, but it is serious enough to affect agriculture (Covey, Schneider, and Thompson, 1984).

The National Academy of Sciences (NAS, 1984) has also assessed the climatic consequences of nuclear war. It has concluded that while large uncertainties exist, the nuclear winter hypothesis may be real for large volumes of smoke; the Academy recommended a national research effort to address major unknowns.

The NCPO was asked in early 1984 by presidential science advisor George Keyworth II to coordinate the organization of an interagency research plan to study the climatic consequences of nuclear war. The NCPO, working with scientists in various agencies and with university scientists, developed a plan which is the basis for an interagency program coordinated by OSTP. Copies of the plan are available from the Office of Science Technology and Policy, Washington, D.C. 20506.

Economic Impact of El Nino-Southern Oscillation Event of 1982-1983

NOAA's Assessment and Information Services Center continues its analysis of the economic impact of El Nino. Monthly departures in the number of weather impacts between January 1983 and April 1983 throughout the world compared with the 5-year average for 1977-81 show several major features (figure 3):

1. Minimal plus or minus departures occurred during the first 7 months of 1982.
2. The sharp increase in the number of above-normal events started in August 1982 and carried on through April 1983.
3. During each of the 9 months beginning in August 1982, the positive departures reached or exceeded the highest departure of the previous 5 years. The average monthly increase in number of events for this 9-month period was four.

On a regional basis (figure 4), the outstanding anomalous major impact area for the August 1982-April 1983 period was Australia, with an almost 400 percent departure from an average derived from the previous 67 months. The Middle East, Japan, West Pacific, and Africa also showed major increases. Of the 11 world regions, only China and South Asia were below average in number of major impacts, while worldwide about 2½ times the average number of events occurred.

Disaster Assistance to Fishing Industry

The National Marine Fisheries Service (NMFS) was very active in monitoring and evaluating the results of the 1982-83 El Nino on the U.S. fisheries off California, Oregon, and Washington. While the El Nino is known as an anomaly in sea surface temperatures along the northwest coast of South America, its related influence, through weather pattern changes, extends to many areas of the Pacific. The catch of West Coast salmon species was reduced 50-90 percent, with similar results noted on California squid and other fisheries. Using the NMFS assessments of these conditions, Congress passed legislation to declare the 1983 salmon season an economic disaster so that the Small Business Administration could make emergency loans available to West Coast fisherman experiencing these losses. This was the first time that a real-time assessment capability developed by NMFS was used as the basis of con-

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gressional legislation to ameliorate an adverse economic impact on the U.S. fisheries industry.

International Weather Anomalies Affecting Agriculture

Anomalous conditions in international crop areas for 1984 are shown in figure 5 and highlighted below.

1. Persistent dryness over the southern Canadian prairies coupled with untimely hot weather during July and August led to a 20 percent decrease in projected wheat production.
2. Unfavorable weather again stressed U.S.S.R spring grains during July and August, resulting in a 10-million ton decrease from earlier estimates of Soviet grain production.
3. Another year of drought conditions in the Sahel zone of West Africa reduced the yield potential and even caused crop failure along the northern margins.
4. Drought extended across central Africa to Ethiopia, worsening the food shortage.
5. The second consecutive failure of summer rains in South Africa led to a more than 50 percent reduction from average in corn production.
6. Persistent dryness during the wheat planting season over eastern and southern crop areas in Australia caused early season pessimism about crop prospects. However, substantial rains came in time to stimulate late planting and vigorous growth. Crop prospects improved significantly.
7. Dryness also affected wheat planting in Argentina; however, substantial rain stimulated wheat planting. Favorable growing season weather has boosted crop production potential.
8. Untimely heavy rain in the south and dryness in the north, coupled with a frost episode in the Brazilian highlands, lowered Brazil's wheat yield potential

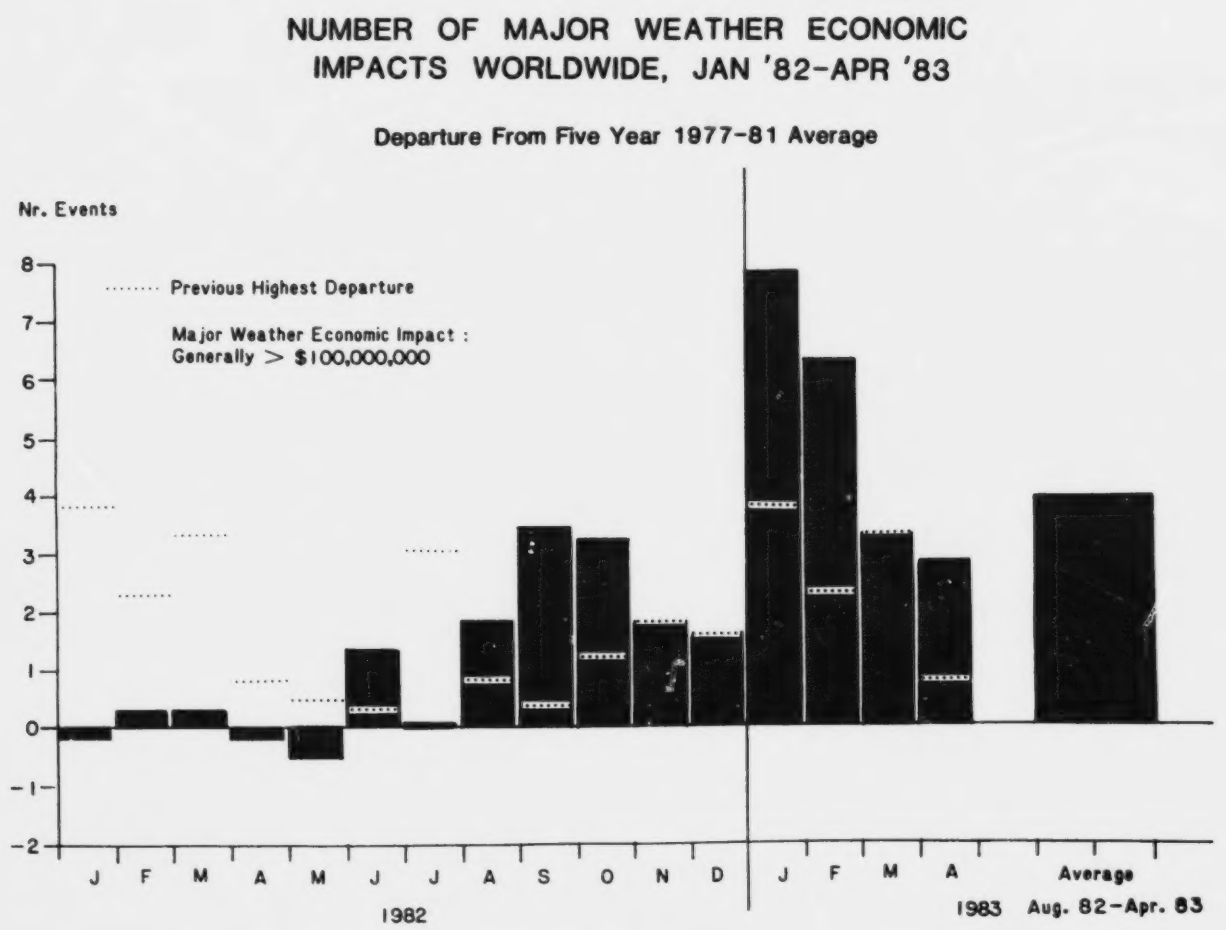

Figure 3.—Estimated number of major weather economic impacts worldwide, January 1982-April 1983. (Departure from 5-year 1977-81 average). Data compiled by AISC/NOAA.

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by 20 percent. Recent showers aided early soybean planting following earlier dryness.

9. Favorable weather and improved technology contributed to a series of increased record yields in the agricultural areas of the North China Plain and China's Yangtze River Valley.
10. Crop prospects in the European Economic Community reached record-setting levels due to timely moisture supply and favorable temperature.

Agricultural and Drought Assistance to LDCs

The Assessment and Information Services Center (AISC) has initiated a program to transfer agroclimatic impact assessment procedures to lesser developed countries (LDCs) in Latin America, South-Southeast Asia, and Africa. This program, which is in various stages of implementation, is being carried out with the help of the Agency for International Development, Office of Foreign Disaster Assistance, and the University of Missouri. Elements of the program include (1) technical training of selected candidates from participating countries; (2) seminar to brief midlevel managers in the meteorological, agricultural, and economic services; (3) in-country technical assistance and coordination with key government officials; (4) evaluation seminar with all participating agencies, including NOAA, USAID and other international agencies such as FAO,

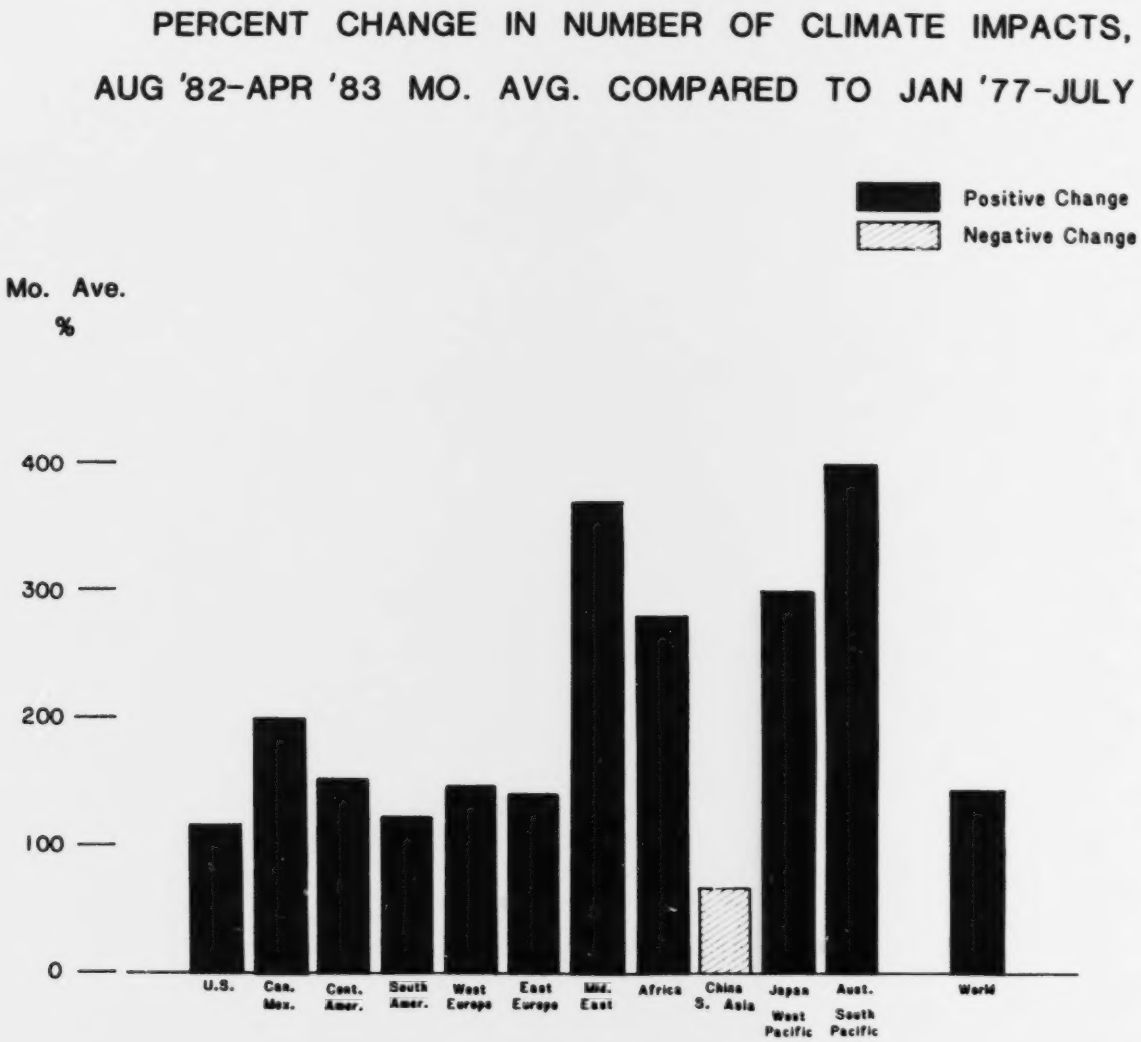

Figure 4.—Percent change in various international sectors in the number of climate impacts, August 1982-April 1983 monthly average compared to January 1977-July 1982. (From AISC/NOAA).

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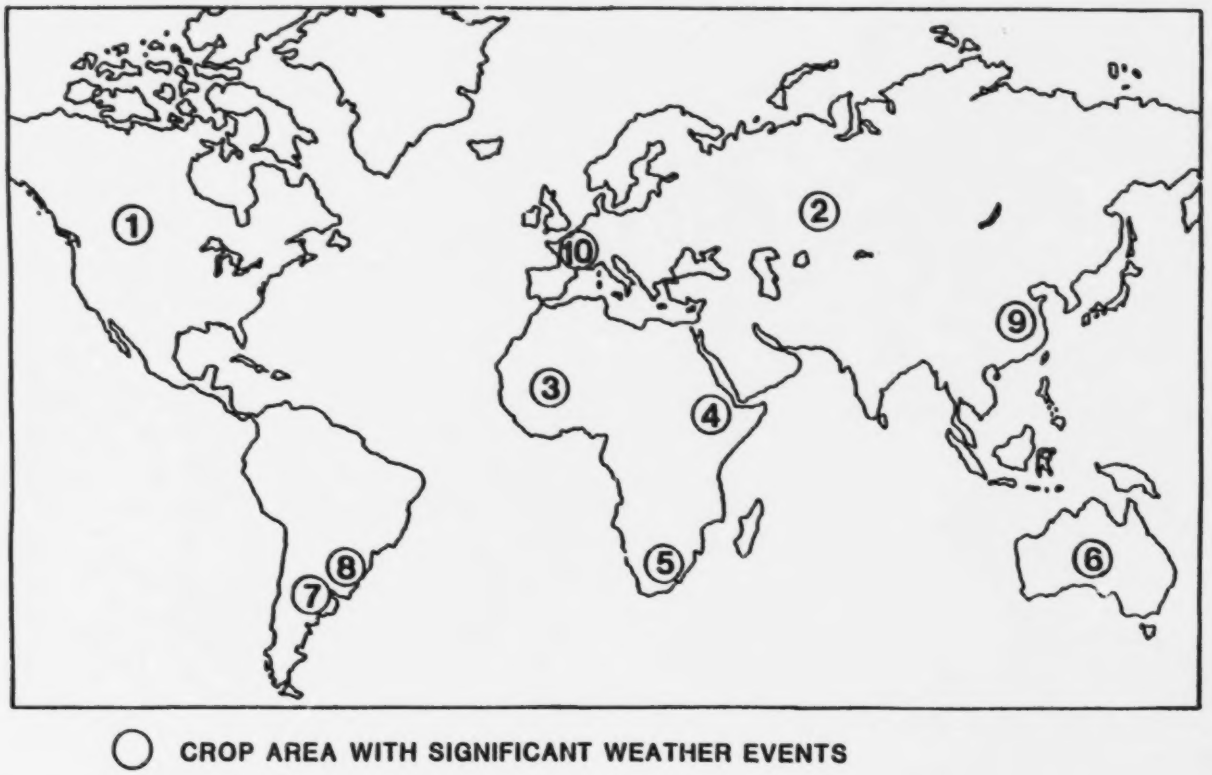

Figure 5.—International agriculture weather anomalies in 1984 prepared by the NOAA/USDA Joint Agriculture Weather Facility.

WMO, UN/ESCAP, etc. Nine South-Southeast Asia countries, five Latin America-Caribbean countries, and four African countries have participated in the program so far. Training packages include a user's manual for microcomputer applications, development and interpretation of selected indices, and procedures to write agroclimate impact assessments.

AISC has also been active in model development during FY 1984. Crop condition assessment index models that use basic rainfall data are being used operationally by the Assessment and Information Services Center to provide early warning of potential food shortages triggered by drought. In selected major production areas of developed countries, plant process growth and development models are being used with daily data to estimate crop yield for maize and wheat. The models are being used with NOAA's advanced very high resolution radiometer (AVHRR) data to detect crop stress and phenological development.

Carbon Dioxide Research

Climate Effect of Trace Gases

At the end of 1983, both the Environmental Protection Agency[1] and the National Academy of Sciences[2] issued separate reports predicting a long-term climatic warming associated with increasing CO_2. However, while general circulation models project an average global warming due to increased CO_2 levels, no direct climate change due to increasing CO_2 has been confirmed. Although the reports differed somewhat in the timing and extent of the warming effects, both emphasized the impact that other trace gases such as O_3, N_2O, and CH_4 have on climate. The continued increases of other radiatively important trace

[1] "Can we delay a greenhouse warming?" EPA, Washington, D.C., 1983.

[2] *Changing Climate*, Report of the CO_2 Assessment Committee. National Academy of Sciences Press, Washington, D.C., 1983.

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gases now indicate that within 50 years their combined climatic effects will be comparable to and perhaps exceed by a significant amount the effects of CO_2 (figure 6). This result underlines the need for a greatly increased understanding of the cycles and radiative properties of trace gases. Some of these needs will be met by a new research and monitoring program—Radiatively Important Trace Species (RITS)—which will be initiated by NOAA in 1985. NSF and NASA are also leading the development of a broad-based research program in global atmospheric chemistry, which is being planned for 1986.

New Calculations of the Global Carbon Budget

The uncertainty in the net biospheric carbon release from contemporary changes in land use has been narrowed significantly, from 0.5-4.7 gigaton (Gt) per year to 0.6-2.6 Gt per year ($Gt = 10^{15}g$). Lower estimates of contemporary terrestrial biospheric releases are the result of detailed analyses of existing soil profile data, the collection of new data on tropical soils, reassesment of tropical forest biomass and land-use conversion rate estimates, and the first detailed analysis of deforestation in the Soviet Union. This has significantly reduced, but not eliminated, the incompatibility between estimates of ocean CO_2 uptake and terrestrial biospheric CO_2 releases. Additional carbon sinks amounting to 1.5-3.5 Gt in 1980 are still required to balance the global carbon budget.

New estimates of early nineteenth century atmospheric CO_2 levels from refined analyses of air trapped in ice cores are 20 parts per million by volume (ppm) higher than values reported in 1983. These higher values are also more compatible with lower estimates of terrestrial CO_2 releases.

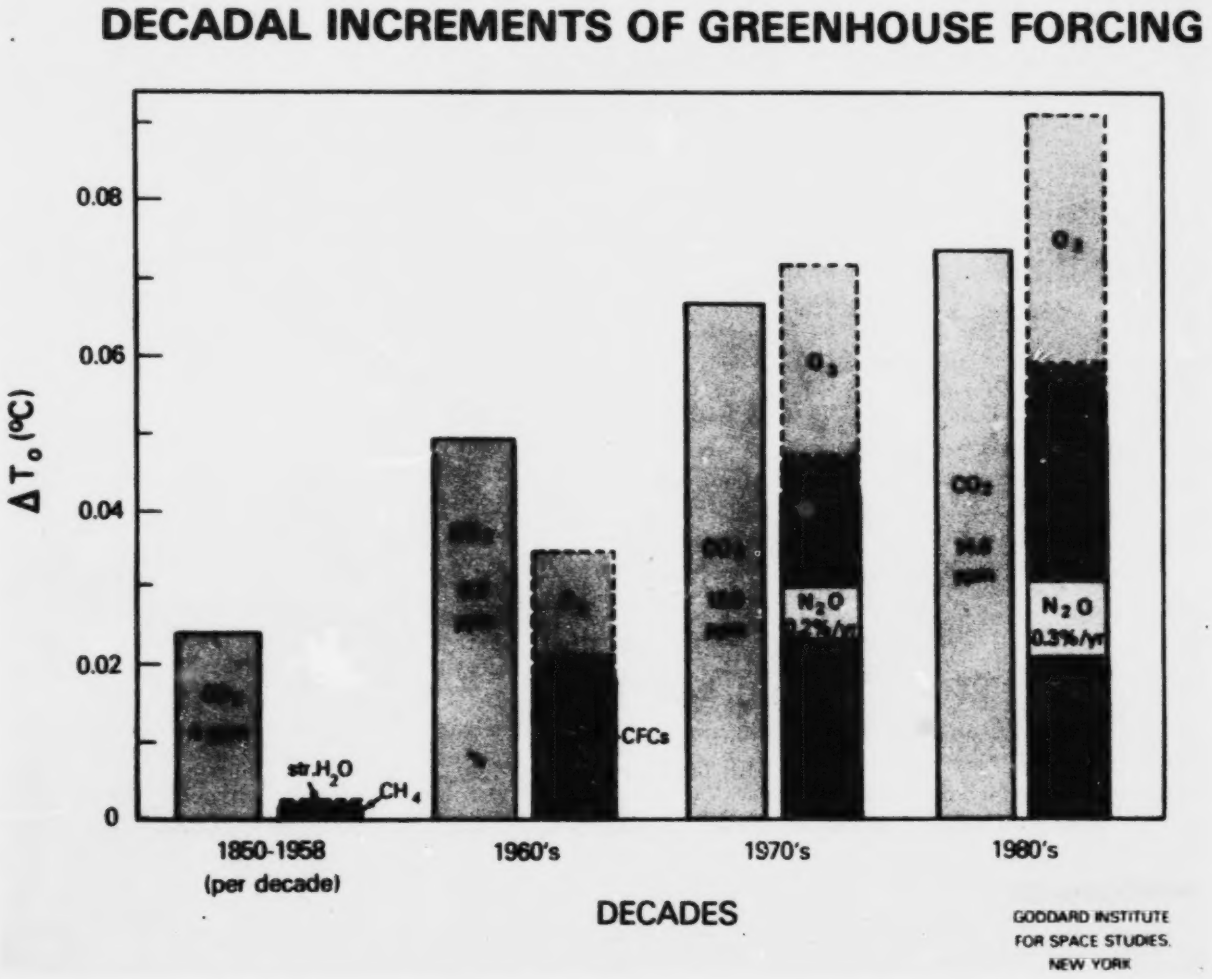

Figure 6.—Increases in climate effect due to CO_2 and other radiatively important trace gases by decades from 1850 to present. Note rising importance of non-CO_2 trace gases as a potential cause of climate change.

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These new findings continued to indicate the existence of unknown or undefined carbon sinks, e.g., the oceans may be assimilating more CO_2 from the atmosphere than currently estimated. Refinements in ocean carbon cycle models have increased CO_2 uptake estimates by 25 percent, which is still insufficient (by 1.5 Gt in 1980) to accommodate the lower estimates of terrestrial biospheric sources. Further progress toward balancing the carbon cycle depends on more realistic and geographically detailed models of the oceans, the land ecosystems, and the interactions between them. Development of such models, in turn, depends on a much improved data base on carbon reservoirs and fluxes, increased in both time and space.

CO_2 in Ice Cores

Analyses of polar ice cores provide convincing evidence that atmospheric CO_2 levels during the last glacial period (18,000 years ago) were 200 ppm, or less compared with 270 ppm during the preindustrial era. The significance of these findings is that a CO_2 change of only 70 ppm, an amount equivalent to the increase over the past century, coincided with the termination of the last ice age. These findings also indicate the complexity of the climate system: comparable changes in atmospheric CO_2 levels have not been accompanied by the same dramatic results and climate interactions must be studied in total to understand the impact of one component of the system upon another.

Recent analyses of ice cores also show fluctuations in CO_2 content that occur at rates comparable to the current burning of fossil fuels (figure 7). These findings were discussed at a meeting organized in 1984 by the U.S. Geological Survey, with support from the National Science Foundation and the U.S. Department of Energy, and sponsorship by the American Geophysical Union. A major outcome

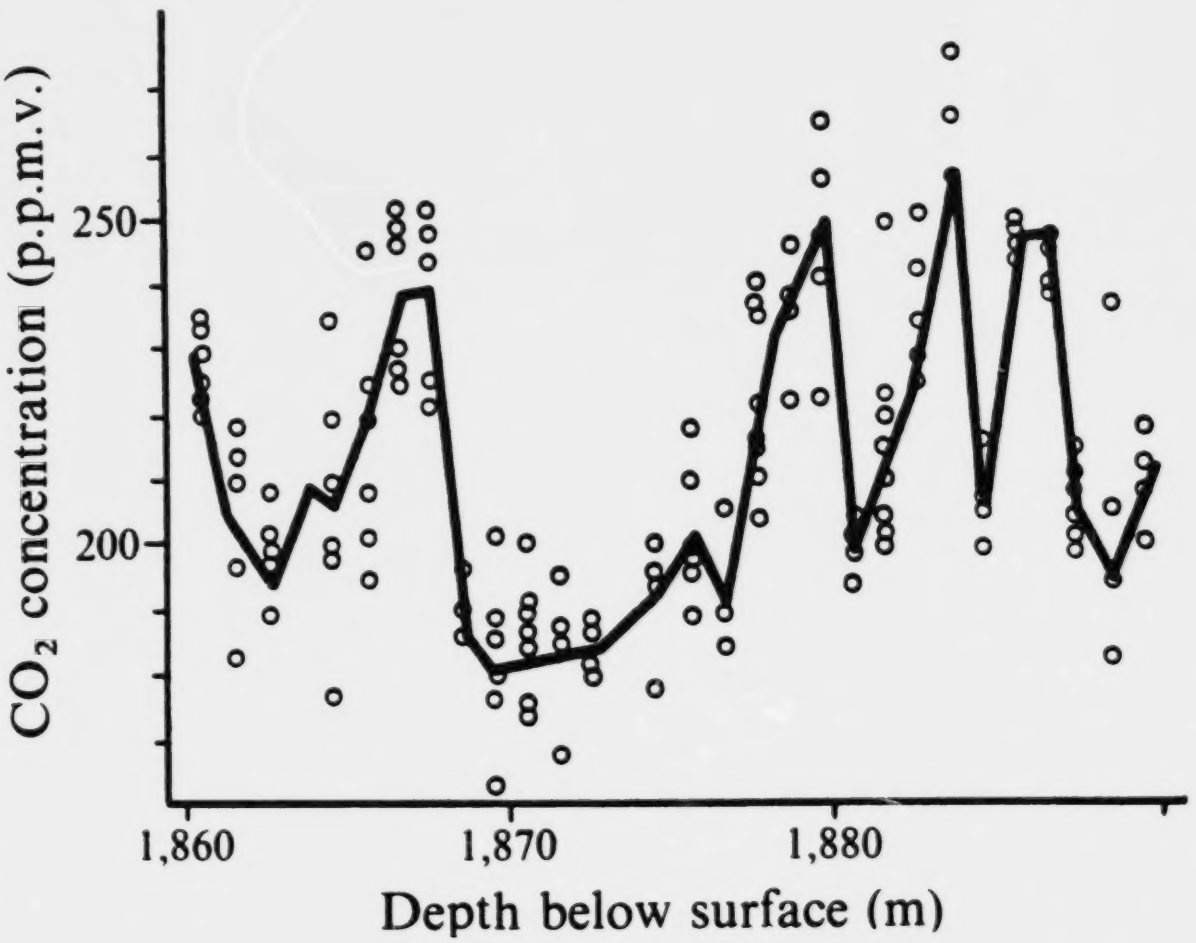

Figure 7.—Atmospheric CO_2 variations measured from air trapped in an ice core collected at site Dye 3 in Greenland. The interval of time represented by this sample is 8,000 years. Data from Hans Oescher (Switzerland).

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of this meeting was the realization that the earth's climate system and carbon cycle are intimately coupled. Not only has the carbon cycle influenced climate through natural changes in atmospheric CO_2, but climate change appears to be capable of altering significant components of the carbon cycle, including atmospheric CO_2. This interaction occurs over a wide range of time scales.

Carbon Dioxide Improves Water-Use Efficiency of Plants

The Agricultural Research Service (USDA) has collaborated with other agency and university scientists in studies of the effect of CO_2 on plant growth. Elevated levels of CO_2 cause increased plant photosynthesis. In addition, stomata (small pores in the leaf through which CO_2 and water vapor are exchanged) partially close in response to increased levels of CO_2, and this decreases plant water loss (transpiration). A concept now being confirmed by new data is that improved water-use efficiency (WUE)[1] resulting from elevated levels of CO_2 will measurably increase growth and dry weight gain of plant organs, including those used for food. This effect is especially important in situations of low water availability.

New results of research on the response of plants to CO_2 enrichment provide improved quantitative values of photosynthetic WUE for several crops and native species. These results are based on research on whole plants that have been continuously exposed in enclosed environments to elevated levels of CO_2 and natural light and temperature. For soybeans and several other species grown in such containment, it is clear that two to three times more CO_2 causes a doubling of the WUE, and for field-grown corn, the WUE may increase by 35 to 100 percent.

The accumulating experimental evidence of improved WUE is an important finding for agriculture and ecology because water stress is often regarded as the single most limiting factor for plant growth. Implications of improved WUE include the protection of plants from drought and other stresses, and possible reduction in the quantity of water required for the plant to complete its life cycle or to produce harvestable yield. Modified WUE could affect water requirements for irrigated croplands and may indirectly affect the distribution of natural plant communities. The possibility exists that CO_2 may function as an effective antitranspirant, thereby making water available for other purposes.

Sea Level Changes

An obvious consequence of global warming, whether due to CO_2 or other causes, would be a rise in mean sea level. During the warming that terminated the last great ice age, for example, sea level rose about 100 meters while the average surface air temperature rose 4 to 5°C. Figure 8 (Barnett, 1984) provides an estimate of the change of global mean sea level over the past century. The slope of the line through the data for the entire 100 years (1881-1980) indicates an average rate of rise of 1.4 millimeters per year. However, the slope of the line through the same data (displaced downward in the figure for clarity) for the more recent 50 years (1931-1980) indicates a more rapid rate of rise of 2.3 millimeters per year.

Until recently, interannual and longer term sea level fluctuations could not easily be distinguished from vertical land motion (subsidence or uplift), making it difficult to estimate actual changes in mean sea level. However, recent advances in geodetic techniques, including the global positioning system (GPS), and NOAA's very long baseline interferometry (VLBI), now make it possible to exactly measure and discriminate between real changes of absolute sea level and apparent changes caused by vertical land motion.

Arctic Haze

Surprisingly large amounts of particulate pollution are found in the Arctic haze layer, which occurs in the Arctic basin during the winter and spring seasons. It evidently results from long-term transport of polluted air from northern midlatitudes. Because the Arctic haze contains significant fractions of graphitic carbon—a good absorber of sunlight—it has been suspected that the haze could significantly modify the radiation balance in the Arctic.

During March and April 1983, a series of flights organized by the National Oceanic and Atmospheric Administration (NOAA) explored the vertical and horizontal distributions of the Arctic haze. Analysis of some data yielded the following results:

1. Substantial concentrations of graphitic particles were found throughout the Arctic troposphere (i.e., in the Alaskan, Canadian, and Norwegian Arctic areas and the North Pole).
2. The absorption optical depths associated with these vertical profiles are large enough to cause a substantial change in the solar radiation balance over a highly reflective surface such as polar ice.
3. Results of initial modeling studies at the Department of Energy's Lawrence Livermore National Laboratory (using data from Lawrence Berkeley Laboratory) have indicated that the soot could be one of the causes of the Arctic warming trends.

From a climate point of view, the most important aspect of the Arctic haze is its effect on the local energy budget. Since

[1] The conventional expression of the efficiency of water to fix carbon is $\text{WUE} = \frac{\text{carbon fixed}}{\text{water consumed}}$

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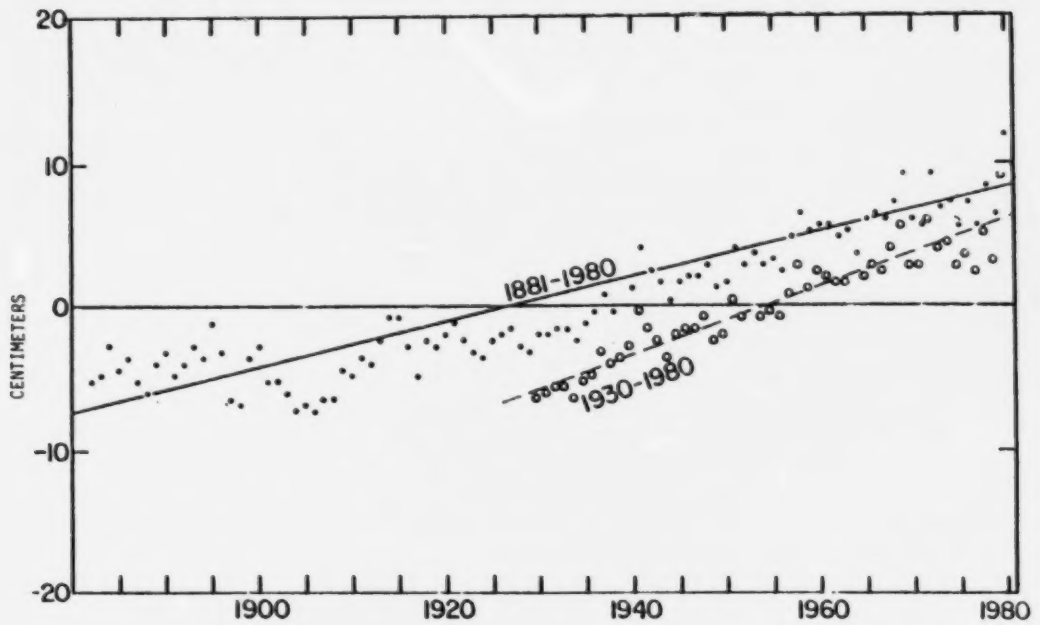

Figure 8.—Estimates of overall average rise of sea level data constructed by T.P. Barnett. Data for the two periods are identical. However, data showing the 1930-1980 rate of sea level rise are displaced downward for clarity.

these effects occur in fall and spring during season transition, they have the potential for affecting various aspects of Arctic ecology.

CLIMATE RESEARCH AND PREDICTION

HIGHLIGHTS

Climate Research

- Effect of El Chichon on stratosphere measured
- Treatment of radiation in climate models improved
- Studies of Tropical Ocean and Global Atmosphere (TOGA) advanced
- Trends in long-term climate change observed

Climate Prediction

- New prediction leads identified
- Third experimental forecast center established at University of Washington

Climate Research

El Chichon and Stratospheric Aerosols

A significant amount of aerosol material from volcanoes has been injected into the stratosphere since 1978. The largest input resulted from the March-April 1982 eruptions of the El Chichon volcano in Mexico (17.3°N, 93.2°W). The resultant stratospheric perturbation is probably the largest in the northern hemisphere in at least the last 70 years. The 48-inch lidar (laser radar) at NASA's Langley Research Center (37°N,76°W) has monitored the stratosphere for the past 10 years, producing a unique history of stratospheric aerosols. A 400-to 600-fold increase in 1982 above the 1978-79 base values resulted from the El Chichon eruption (figure 9).

Recent airborne observations of the El Chicon material show it to be generally a single broad layer from 37°N to 76°N latitude. The El Chichon material is difficult to define above 76°N because of interference with polar stratospheric clouds.

Improvement in Treatment of Radiation in Climate Models

Numerical models of the physical processes that occur in the earth's atmosphere have been used successfully to make short-term weather forecasts. Now, these models are being used to make longer term forecasts and to study climate variability. On these longer time scales, it is important to simulate correctly the earth-atmosphere system's radiation budget. Since accurate computations of the radiative field are very time consuming, progress in this direction had been slow until the advent of fast vector processing computers and broadband radiation parameterizations that are fairly accurate and computationally efficient. One

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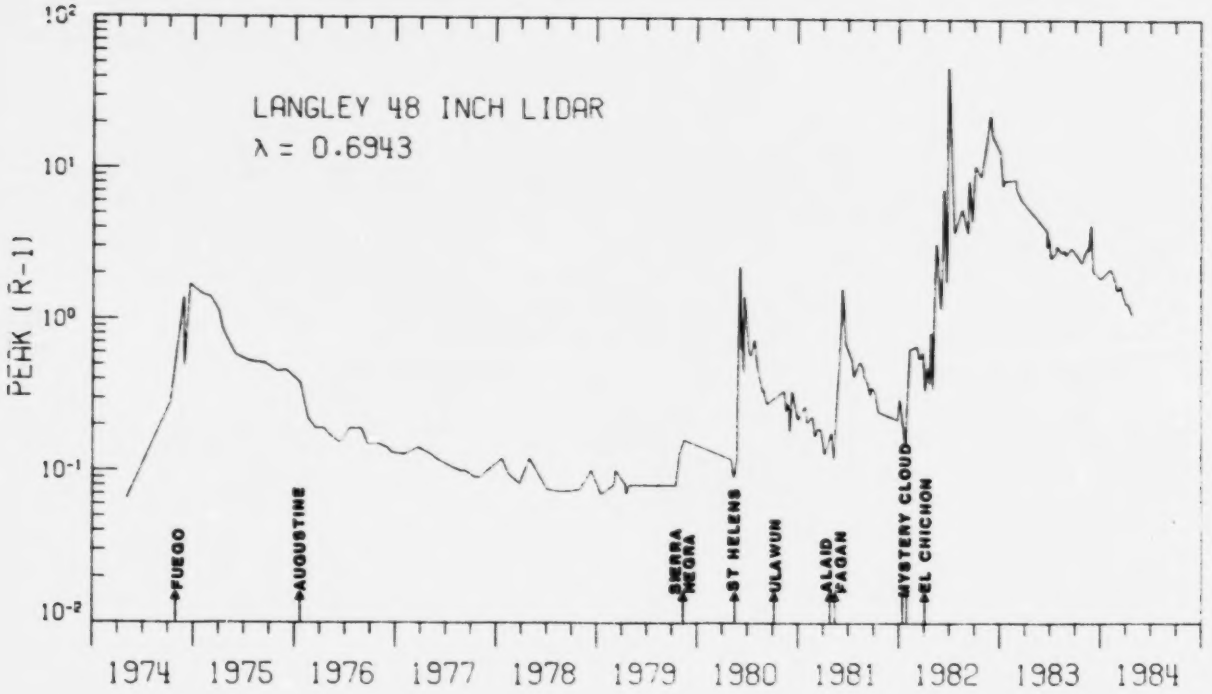

Figure 9.—History of stratospheric aerosols from ground-based lidar data taken at 37°N, 76°W. Major volcanic eruptions noted during 1974-84.

such scheme has been implemented in a climate general circulation model in the Laboratory for Atmospheres at Goddard Space Flight Center. The model is run on the Cyber 205 computer and calculates the radiation field every simulated hour from the internally generated cloud, humidity, and temperature fields. An example from this model is the monthly mean outgoing longwave flux for July shown in figure 10 compared with the same quantity derived from measurements made with the narrow-field-of-view instrument on the Nimbus-7 satellite. The model correctly simulates several features of this radiation field, both in magnitude and location. Further work on the parameterization of cloudiness is expected to improve the simulation, especially in regions of intense convection and in other cloudy areas. Since the efficient and accurate treatment of radiation has been a serious deficiency of major global climate models, this is an important contribution toward the numerical simulation of climate out to the annual time scale.

Progress in TOGA and Related Modeling

The United States and other nations' scientists have begun preparations for a 10-year research effort on the interannual variability of the tropical oceans and global atmosphere (TOGA). While the international TOGA program does not begin until January 1985, the U.S. TOGA observing system began in 1984. The TOGA observing system in the Pacific Ocean includes island meteorological stations, tide gauges, current meters and subsurface temperature moorings, and expendable bathythermographs (XBTs) collected by ships-of-opportunity.

Diagnostic Study of 1982-83 El Nino Event

The NOAA Climate Analysis Center has completed an extensive series of analyses and diagnostic studies of the historic 1982-83 El Nino-Southern Oscillation (ENSO) episode. These studies, together with supporting atlases and background documentation, constitute by far the best documentation to date of the global aspects of one of these episodes. They provide a unique resource for use in the development and testing of ocean and atmospheric models that simulate ENSO.

Development of New SST Analysis Technique

The NOAA Climate Analysis Center has developed an improved SST analysis which makes use of both in situ (ship and buoy) and satellite observations. The satellite retrievals provide superior data coverage and relatively small error variance when compared with in situ observations

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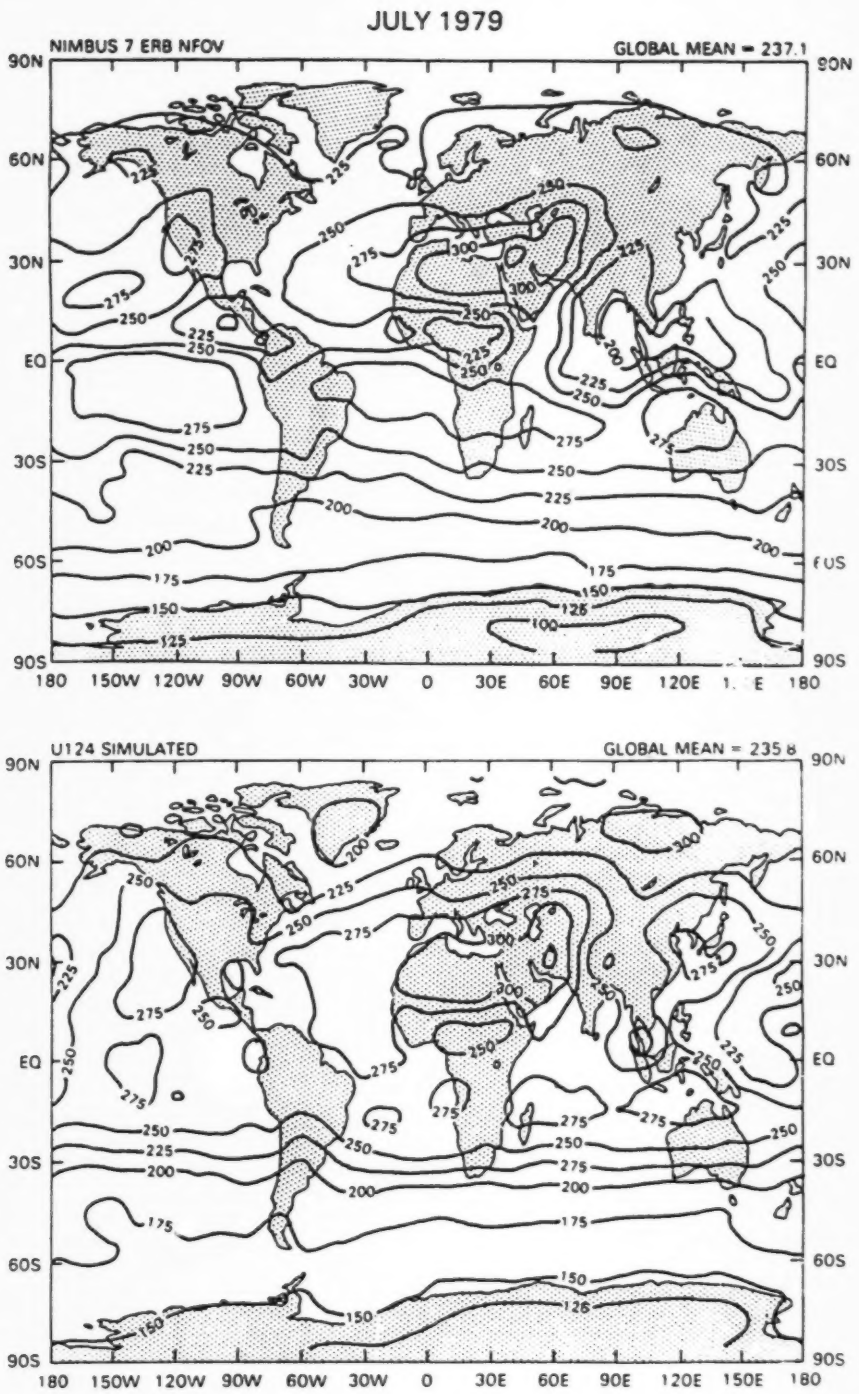

Figure 10.—Comparison of calculated global radiation for July 1979 from NASA global climate model and measured radiation at the top of the atmosphere from Nimbus satellite.

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but sometimes exhibit biases that are not independent of time or location. The new analysis technique uses the in situ data to define "benchmark" temperature values in regions of dense observations and the satellite data to define the "shape" of the field between these points. Thus the technique emphasizes the advantages of each data type to produce an analysis which is generally superior to that obtained from either set separately. The blended technique has been used to reanalyze the mean monthly SST fields during the 1982-83 El Nino event.

Model Simulation of Tropical Anomalies

One objective of the TOGA program is to develop ocean models that accurately simulate the redistribution of heat in the oceans during an El Nino event. Combined work supported by NOAA and NSF has tested a new ocean model on a high-quality Atlantic data set. The model reproduces many of the observed features in the equatorial Atlantic, thereby encouraging scientists to examine Pacific simulations with greater interest. Model simulations indicate that eastward heat transport during an El Nino is affected by both subsurface currents on the equator and a surface current (equatorial countercurrent) at about 5°N. The increased accuracy in the simulation of the transport field aids in planning the monitoring network for the TOGA Program.

The Geophysical Fluid Dynamics Laboratory (GFDL) has also developed three-dimensional, high-resolution models for the equatorial Pacific and Atlantic oceans. The models, with twenty-seven vertical levels, are forced by surface winds (e.g., from NMC global wind analysis) and provide realistic simulations of the low frequency variability in these tropical oceans based on tests with available data, such as that from EPOCS in the Pacific and from SEQUAL in the Atlantic. Application of the model to the 1982-83 El Nino showed excellent results, leading to a 1985 effort to implement the model operationally in near real-time at the NMC/Climate Analysis Center.

The GDFL has also completed a 15-year integration of an atmospheric general circulation model with prescribed-time varying sea surface temperatures that are in accord with observations in the Pacific Ocean between 30°S and 30°N. The model produced an excellent simulation of the atmospheric El Nino-Southern Oscillation phenomena, especially in the tropics; a control run with specified climatological sea surface temperatures did not produce such an effect. These results offer strong encouragement that appropriately coupled atmosphere-ocean models can achieve self-consistent simulations of the El Nino-Southern Oscillation phenomena.

GCM Sensitivity to 1982-83 Equatorial Pacific Sea Surface Temperature Anomalies: Intercomparison Among Nine GCM Results

The winter of 1982-83 witnessed the most outstanding example of large persistent sea surface temperature (SST) anomalies over the equatorial Pacific and related circulation anomalies over many parts of the globe. Since the influence of tropical SST anomalies on atmospheric circulation, locally as well as globally, holds major promise for predicting short-term climate, it is considered important to understand the mechanisms through which SST anomalies influence the atmospheric circulation. Several climate modeling groups around the world have conducted sensitivity experiments for these observed SST anomalies using their respective GCMs. During the Sixteenth Colloquium on Hydrodynamics, held at Liege, Belgium, in May 1984, a session was devoted to intercomparisons of the results from the various modeling groups.[4]

All the models correctly simulated the eastward shift of the rainfall maximum over the central equatorial Pacific. There were quantitative differences in the simulated rainfall anomaly. The consistency of the results using such widely different GCMs confirmed the earlier hypothesis that tropical SST anomalies can produce significant and predictable changes in tropical rainfall and circulation. Similarities among the midlatitude simulations were not so obvious.

An example of the tropical response as simulated by the GLAS climate model is shown in figure 11 (Fennessy et al., 1985). The upper panel shows the observed SST anomaly for January 1983. The middle panel shows the rainfall anomaly simulated by the model and the bottom panel shows the "observed" rainfall anomaly as estimated from the observed outgoing longwave radiation anomaly using empirical relationships developed at the NOAA Climate Analysis Center. It is rather remarkable that the structure and magnitudes of a GCM simulated rainfall anomaly are in close agreement with those of the observations.

Intraseasonal Variations and the El Nino-Southern Oscillation

Intraseasonal variability of convective activity over the tropical Pacific was studied using the outgoing longwave radiance produced by NOAA from the imaging radiometers on the polar-orbiting operational meteorological sat-

[4] Participants included: M. Blackmon, National Center for Atmospheric Research,; G. Boer, Canadian Climate Center; V. Cubash, European Center for Medium-Range Weather Forecasting; S. Esbensen, Oregon State University; Julian McCreary, NOVA University; J. Shukla, Goddard Laboratory for Atmospheres; A. Oort and N.C. Lau, Geophysical Fluid Dynamics Laboratory; T.N. Palmer and D. Mansfield, British Meteorological Office; R. Sadourny and R. Michand, Laboratoire de Meteorologie Dynamique; M. Suarez, Goddard Laboratory for Atmospheres.

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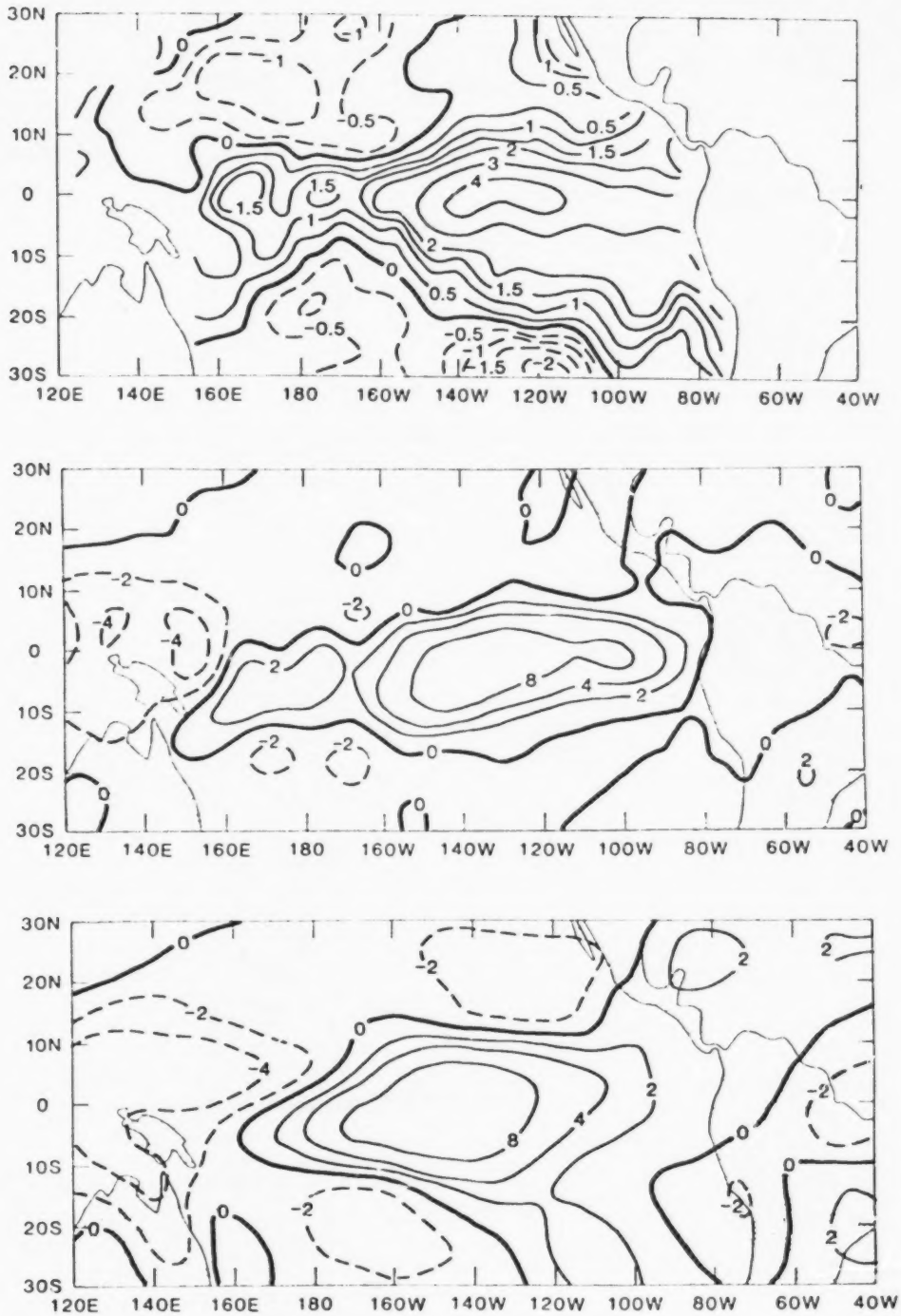

Figure 11.—Comparison of simulated and observed rainfall anomaly. Top panel is observed SST anomalies for January 1983. Middle panel is simulated rainfall with GLAS (NASA) climate model; bottom panel is observed rainfall. Model results are in good agreement with observed conditions (after Fennessy et al., 1985).

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ellites. A spectral peak of 30-60 days was found in tropical convection, confirming earlier findings of an oscillation of the same periodicity over the tropical western Pacific. This oscillation appears to be on a planetary scale and to possess both stationary and eastward propagating characteristics. Except for the intensity, there is a close resemblance between the spatial structure of these 30-60-day waves and the observed climate anomalies in the tropics during an El Nino-Southern Oscillation (ENSO). Work is now in progress to find further evidence of such a connection and to examine possible triggering mechanisms for ENSO.

Atmospheric Water Vapor Anomalies Associated with the 1982-83 El Nino

Large changes in the atmospheric water vapor over the tropical and subtropical oceans resulting from the El Nino event of 1982-83 were detected in an analysis of the microwave measurements made by the Nimbus-7 scanning multichannel microwave radiometer. An illustration of the changes that took place during January 1983, when the El Nino was near its peak, is shown in figure 12. The pattern, showing a large positive anomaly in water vapor amount in the equatorial Pacific east of the date line, with a marked decrease in the western Pacific and in the subtropics on either side of the equator, bears a striking resemblance to the SST anomalies and the outgoing longwave radiation (OLR) anomalies that have previously been associated with such events. These patterns reflect the eastward shift of the rising branch of the Walker circulation, the east-west circulation associated with the Southern Oscillation, which weakens during an El Nino.

The quantitative changes in water vapor amount are the effects of a modified circulation pattern in the atmosphere and SST anomalies that are, in turn, associated with a modified circulation pattern in the oceans. Increased convergence in the planetary boundary layer and positive sea surface temperature (SST) anomalies both contribute to increased water vapor. Divergence (or reduced convergence) in the planetary boundary layer and negative SST anomalies would lead to a decrease in water vapor. This information is particularly important for calculating moisture transport in the tropics and for understanding the role of air-sea interactions in the development of El Nino. This is the first time that such quantitative data have become available, adding to our growing body of knowledge on the El Nino and its climatic effects.

Long-term Ocean Temperature Changes

Until recently, decadal-scale ocean temperature fluctuations, both surface and deep water, have received relatively little attention. National Science Foundation-supported research has now demonstrated a significant cooling of North Atlantic and North Pacific surface waters since the early 1960s (figure 13). Possible feedback effects on climate are still uncertain, but some preliminary results indicate a significant weakening of the East Asian monsoon over the same time period.

Determination of any long-term changes in the large-scale characteristics of the deep ocean circulation would be an important clue in understanding the climatic interactions of the ocean and atmosphere. A baseline for comparison can be derived from the surveys of the North Atlantic conducted during the International Geophysical Year in the late 1950s. In the summer of 1981, the *R.V. Atlantis II* reoccupied two of these transatlantic sections at latitudes of 42°N and 36°N.

In contrast to the surface temperature trend shown in figure 13, significant warming was observed to have occurred in an ocean-wide band between depths of 700 and 3,000 m. The maximum temperature difference observed was 0.2°C. The historical temperature-salinity curve was unchanged, on the other hand, suggesting that locally the warming is caused by a downward displacement or thickening of the central water mass due to large-scale motions. Tracer data also suggest that a direct influence from the surface layers is not to be expected on decadal time scales. The mass and heat flux convergence rates implied are too small to be directly detectable, but the change in mean water column properties implies a vertical column expansion of several centimeters.

On what time scale do such changes occur? Only one systematically acquired data set exists to answer this question: a series of fortnightly hydrographic soundings made in deep water near Bermuda since the early 1950s. These data, in the middle of the subtropical gyre, also show a clear warming trend in middepth waters.

These studies raise global questions. How does the surface variability depicted in figure 13 relate to changes in deep ocean heat storage? Current models which predict a general surface warming in response to CO_2 increases in the atmosphere, but only gradual effects in the deep waters, may as yet be too simplistic. The observations definitely open the possibility that the observed rate of sea level change, of about 0.1 m per century, may be due in part to thermal expansion in the deep oceans.

Climate Prediction

New Prediction Leads Identified

NSF-supported research has produced some encouraging developments in prediction. Researchers at Florida State University are using monthly wind analyses from NOAA/CAC to update a simple coupled ocean-atmosphere model that predicts thickness of the warm water layer in the equatorial Pacific. Furthermore, incorporation of the CAC wind

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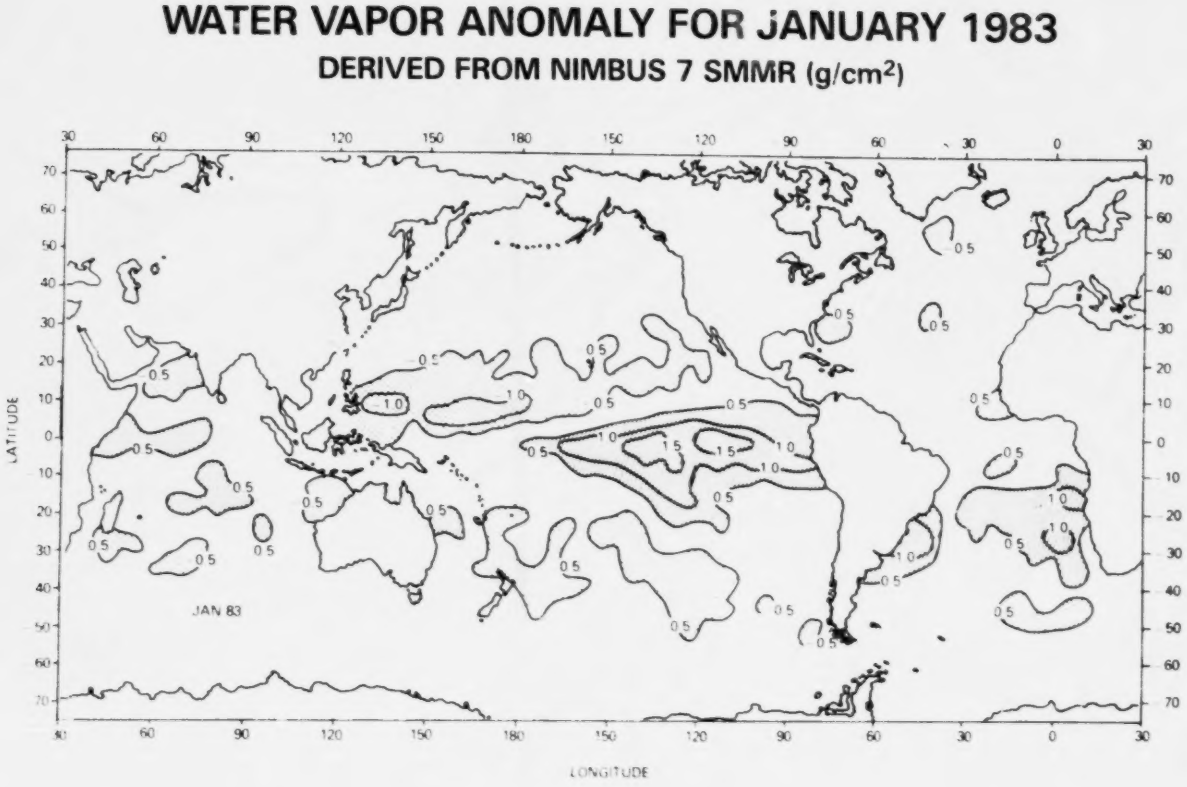

Figure 12.—Water vapor anomaly for January 1983, derived from Nimbus 7 scanning multichannel microwave radiometer. Pattern shows a large anomaly in water vapor all through the time of maximum El Nino in 1983. From NASA/GLAS.

analysis in near real-time means that the model can be used to crudely forecast El Nino onsets. A surprisingly good relationship between forecast and observed temperatures over a 5-year interval has encouraged researchers to develop this model further.

Researchers supported by the National Science Foundation have also demonstrated for the Atlantic Ocean a relationship between rainfall in northeast Brazil and several ocean-atmosphere variables. Efforts are now being made to acquire these data in near real-time in order to use them for predicting rainfall in this drought-prone region.

Progress has also been made in developing improved statistical-dynamical forecast techniques. National Science Foundation-supported research has resulted in a refined statistical analog prediction technique for the East Coast of the United States that for the first time demonstrates significant skill in predicting monthly temperatures. Further work with a statistical-dynamical climate prediction model has indicated that certain nonlinear terms do not have to be included. If true, this result is extremely important because it would greatly simplify the use of this class of models for prediction.

Monthly forecast experiments at NOAA/GFDL were carried out for eight January cases with a new GCM model. These experiments show that monthly forecasts appear feasible, though the current skill is marginal. Refining some of the small-scale physics has improved the experimental monthly forecasts by better simulating blocking pressure ridges and better placing the geographical locations of planetary-scale waves in the westerlies.

It has been possible to document for the first time with the GLAS/GCM (at the experimental forecast center) a case in which larger amplitude atmospheric anomalies are driving sea surface temperature (SST) anomalies in the southern hemisphere. During January 1979, strong anomalous stationary waves were found in both the South Atlantic and the South Pacific. A strong correlation between cyclonic circulation and negative SST anomalies was observed and indicates that the atmospheric anomalies are causing the SST anomalies, which in turn provide a negative feedback to the atmosphere. This is because a sta-

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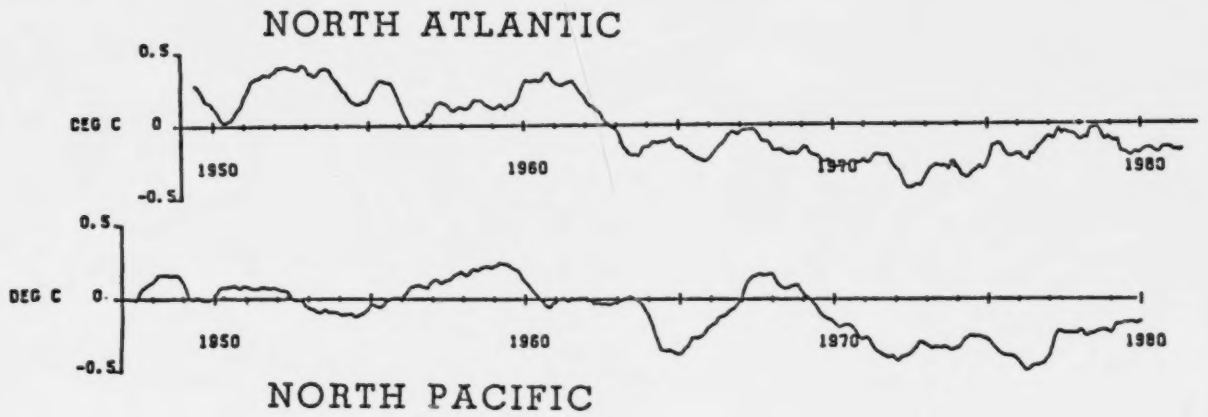

Figure 13.—Surface water cooling since the 1960s. North Atlantic analysis from Daniel R. Cayan, Scripps Institution of Oceanography (private communication). North Pacific analysis from Douglas, Cayan and Namias, Monthly Weather Review, Dec. 1982.

tionary atmospheric cyclonic circulation will tend to reduce upwelling and cooling in the ocean surface, and at the same time the associated cloudiness will reduce the summer insolation. Conversely, the presence of clear regions of anti-cyclonic circulation, with the associated downwelling, will tend to warm the resulting stable mixed layer.

The Experimental Forecast Program

A third experimental climate forecast center has joined the program. Established at the University of Washington under the leadership of Professor John M. Wallace, the new center will concentrate on the implications for long-range prediction based on studies of the El Nino and Southern Oscillation and other very large-scale, definable phenomena. The center is cosponsored by the NCPO and the NOAA TOGA (Tropical Ocean, Global Atmosphere) Project Office.

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III. National Climate Program Office Activities

Planning and Coordination

The NCPO is the lead entity responsible for administering the National Climate Program. Management functions of the NCPO include planning, oversight, coordination, budget analysis, and program evaluation. Additional program responsibilities mandated by the NCP Act cover the federal-state climate program (see the section on regional climate centers), development of experimental forecast centers (see the research section), and coordination of international aspects of the program.

The NCPO has initiated the development of a new climate program plan. The first Five-Year Plan was initially prepared in 1979 and has since become obsolete due to program developments. A new Five-Year Plan for the period 1986-1990 will be prepared in 1985. An interim climate plan to cover the period 1984-1986 has been prepared and is available from the NCPO. The purpose of the interim plan is to bring the goals of the NCP more in line with actual activities and interests of the federal agencies. The NAS is organizing a workshop at Woods Hole in the summer of 1985 to review past achievements of the NCP and recommend priorities for the next 5-year period.

INTERNATIONAL ACTIVITIES

Part of the congressionally mandated responsibilities of the NCPO is to function as the focal point for international aspects of the National Climate Program. U.S. international climate activities remain centered around the World Climate Program (WCP), administered by the World Meteorological Organization, and bilateral agreements. The NCPO assists official U.S. delegations in preparing position papers for meetings of international agencies and organizations both on a routine basis (yearly meetings of the WMO Executive Council, UNEP Governing Council, or bilateral exchanges) and on an ad hoc basis (commitments meetings, planning meetings, etc.). Issues related to U.S. involvement in international climate activities should be brought to the attention of the NCPO as they arise so they are addressed as needed in these position papers.

With respect to the World Climate Program, the following activities were accomplished in 1984:

World Climate Program Publications Series. A large number of reports, bibliographies, plans, and studies related to the World Climate Program are produced each year by the World Climate Program Department of WMO. The series presently numbers 84 and is given in the Appendix. Many of these reports are available through the NCPO.

CLICOM. The climate computer system of the World Climate Data Program (WCDP) project provides microcomputer hardware and software to less-developed countries in order to improve their use and preparation of climate data. The first microcomputer system under CLICOM was initiated in Tanzania during 1984. This U.S.-designed system (by the Oklahoma Climatological Survey) is one of what may be several CLICOM systems by various U.S. and international groups which will become available over the next few years.

Climate System Monitoring. The World Climate Data Program has begun issuing a monthly bulletin on an experimental basis which highlights significant large-scale temperature and precipitation anomaly patterns over the globe. The major contributor to the bulletin is the Climate Analysis Center of NOAA, NWS. Copies of the monthly bulletin are available through the NCPO.

International Satellite Cloud Climatology Project (ISCCP) and the First ISCCP Regional Experiment (FIRE). The ISCCP continued processing radiance data during 1984 despite the loss of the U.S. GOES-E satellite in July (with no replacement available until at least late 1985), and problems which occurred with the Japanese GMS satellites until GMS-3 became operational in September. The first cloud data are expected to be archived before mid-1985. An international effort has been started to investigate methods of verifying the derived global cloudiness. A FIRE Project Office was established in September by NASA under the management of David McDougal, NASA Langley Research Center. The initital meeting of the FIRE scientific experiment team was held during November at NCAR in Boulder, Colorado. The team selected Dr. Stephen Cox and Dr. David Randall as team co-chairmen. Fur-

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ther meetings of the FIRE scientific experiment team are planned during 1985 in order to structure the national research program to available resources.

Tropical Ocean—Global Atmosphere (TOGA). A major international conference was held in Paris during September 1984 for presentation of the scientific rationale behind TOGA and consideration of a draft plan for the project. A final international plan for TOGA is expected during early 1985 with a commitments meeting on TOGA and other WCRP activities planned for early 1986. The United States agreed to host the International TOGA Project at NOAA, ERL in Boulder, Colorado. Dr. Rex Fleming was named the director with assistance by U.S., Canadian, and Indian scientists. The office began operations in November 1984.

World Oceans Circulation Experiment (WOCE). Planning for U.S. participation in the WOCE has begun with several workshops and meetings during 1984. An international ocean model intercomparison is under way. The United Kingdom has offered to host the international project office for WOCE.

International Satellite Land Surface Climatology Project (ISLSCP). Initial support for the ISLSCP has come from the World Climate Impacts Program, led by UNEP. ISLSCP intends to develop algorithms to convert satellite radiances into land surface parameters (soil moisture, albedo, precipitation, etc.) in order to develop a 20-year global climatology.

The 9th meeting of Working Group VIII of the US-USSR Agreement on Cooperation in the Field of Environmental Protection was held in Moscow, Suzdahl, and Kiev during December 1983. The primary accomplishments over the past year under W.G. VIII have been the completion of a three-volume joint monograph on the *Late Quaternary Environments of the United States and the Soviet Union* (University of Minnesota Press), the conclusion of a six-week joint oceanographic research cruise in December 1983 to sample atmospheric and oceanic trace species over the Pacific, and a joint symposium on Small Gas Components in Vilnius, Lithuania during August 1984.

The fifth meeting of the U.S.-PRC Joint Working Group on Cooperation in the Field of Atmospheric Science and Technology took place in February 1984 at NCAR. The bilateral effort has an active training program along with ongoing programs in agriculture and climate, monsoon research, mountain meteorology, and climatic studies.

The fifth meeting of the U.S.-PRC Joint Working Group on Cooperation in the Field of Marine and Fishery Science was held in Seattle in August 1984. In addition to continued participation in the several project areas of the bilateral agreement, a major joint program related to the TOGA project was agreed upon.

The ninth Joint Session on U.S.-France Cooperation in Oceanography was held in October in Paris, France. Specific areas of cooperation that relate to the climate program include: (1) the development of subsurface "pop-up" drifters for application in the WOCE program; (2) implementation of advanced VLBI/GPS geodetic techniques for monitoring sea level; (3) the use of satellite altimetry for the study of large-scale ocean circulation; (4) the deployment of XBTs from ships of opportunity to support the TOGA program.

Under the U.S.-India Bilateral on Monsoon Research, the United States began receiving twice-daily INSAT-B data in April 1984. The data are expected to be transmitted routinely to NCAR in the future and to be included with the international data for the ISCCP.

The Department of Energy has begun negotiations with the People's Republic of China to form a bilateral agreement to study regional aspects of CO_2-induced climate change. The agreement is expected to be concluded during 1985.

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IV. Evaluation

This section reviews specific achievements relative to milestones specified in the Interim Climate Plan FY 1984-1986.

PROVIDING CLIMATE PRODUCTS AND SERVICES

Generation and Dissemination of Climate Information

FY 1984 Milestones

- Upgrade computer capability at NCDC. (NOAA)
- Continue expanding current climatic data sets and products for near real-time access. (NOAA/NCDC/CAC)
- Publish Part 1 of *North American Climate Data Catalog.* (NOAA)
- Complete the National Environmental Data Referral Service and provide on-line service to state and regional centers. (NOAA/NESDIS)
- Develop pilot climate data system. (NASA)
- Review continuous solar monitoring with repaired Solar Maximum Mission (SMM) satellite; bring processing of Nimbus-7 data up to current time (NASA).
- Develop the weekly and monthly climate bulletins for distribution by the WMO and as the first step in designing a global climate alert system. (NOAA/CAC)
- Improve energy-related weather information. (NOAA/CAC)

The main goal of the NCP in FY 84 (and in the next 3 years) is to improve climate data networks and the reliability and completeness of existing climate data sets. Toward this goal, the NESDIS central computer in Ashville, N.C. was upgraded to a Sperry model 1100/62. The increased performance of the central computer represents a significant milestone in NOAA plans to keep abreast of the latest trends in computer technology. Coincident with the new computer system, new processing systems have been developed to handle the millions of observations received each year by NCDC. The new systems are highly interactive to allow the proper man-machine mix in the quality control procedures.

The primary mission of the NCDC is to archive the official weather records of the United States (from which climatic averages are derived) and to process, summarize, and publish data sufficient to describe the climate of the United States. NCDC products influence many economic segments of the United States. For example, the official climate data at NCDC are used to establish climatic normals and extremes for setting building codes or insurance standards. Knowledge of the long-term behavior of climate becomes critical in engineering, construction, water allocation, fuel distribution, and agriculture. A wealth of climate data are archived at NCDC, and in 1984 NCDC reached a major milestone in a current program to improve data availability. There is now available for the first time a digital data base of station history for more than 20,000 cooperative, NWS, Federal Aviation Administration (FAA), and military surface observing stations.

The NCDC has also summarized and published historical climate data for the period 1895-1983. The publications include:

> *Historical Climatology Series (HCS) 6-1,* "Statewide Average Climate History—1895-1983."
>
> *HCS 3-2 to 3-5,* "Atlas of Monthly and Seasonal Temperatures from the Long-Term Mean (1895-1983) for the Contiguous United States."
>
> *HCS 4-3,* "Regional and National Monthly, Seasonal, and Annual Temperature Weighted by Area, 1895-1983."
>
> *HCS 6-1* presents time series of temperature, precipitation, degree days, and drought in both tabular and graphical form. *HCS 3-2* to *3-5* detail information on the spatial coherence and intraseasonal variability of temperature anomalies. The NCDC's *HCS 4-3* provides information on the temporal variability of regional and national temperatures.

The National Climatic Data Center has further added to its data availability and dissemination methods through two new features acquired during 1984. The Service Records Retention System (SRRS) contains data and information available on NWS's AFOS network. Products include original observations as transmitted via AFOS, forecasts, warnings, and analyzed maps.

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NCDC also acquired the ability to produce diskettes in over 130 different formats (each manufacturer of personal computers requires differently formatted diskettes). This new digital medium, combined with new user-friendly digital data structures, greatly increases the availability of climatic data, at reasonable costs, to the end user.

NOAA's Assessment and Information Services Center continued development of the National Environmental Data Referral Service (NEDRES), a computer data base which allows users to find holders of climatic and environmental data. The data base is accessible via computer terminal by local phone call from anywhere in the United States or the world. There were about 16,500 data descriptions in the data base in 1984. The *North American Climate Data Catalog*, Part I, was published. It contains descriptions of over 600 climatic data sets for the United States and Canada.

The CAC continued to expand its user products and developed procedures for identification and description of long-term drought. Weekly Palmer drought and crop moisture indices are being calculated year round and disseminated via AFOS and published in the *Weekly Weather and Crop Bulletin*. CAC's high density precipitation data file now includes data from U.S. river forecast centers and the climate assessment data base. Rainfall totals are now being averaged over many U.S. climate divisions. Probability projections of the Palmer drought index, 3 months in advance, are being computed monthly and are now available on CAC's microcomputer. Near real-time monthly precipitation deficiency indices for U.S. climate divisions are being computed monthly and also are now available on CAC's microcomputer.

NASA continues development of a pilot climate data system designed to provide comprehensive information describing selected NASA climate-related satellite data. The volume of satellite data presents problems of storage and accessibility. A major problem confronting climate researchers is determining what data exist, or are planned, and which are appropriate to support their research effort. The objective of the climate data system is to provide users with technical information about selected climate parameters and the associated sensor measurements from which they are derived. The NASA Climate Data Catalog will be available at the end of 1984 and will be described in next year's annual report.

Regional Climate Centers

Milestones

- Expand Nebraska Automated Weather Data Network to adjacent Great Plains
- Test feasibility of near real-time weather climate information for the Midwest

Two regional centers are now in operation.

The automated network in the Midwest grew considerably in 1984 to a total of forty-four. Many of these stations have been initiated by individual states. The system demonstrates successful federal-state cooperation in establishing a system for data collection and dissemination. The data are available directly to users, and to commercial firms that produce value-added information products, such as irrigation scheduling recommendations, needed by agriculture and business.

While progress is being made in selected areas of data management and information dissemination, much remains to be done to achieve full potential for increasing beneficial uses of climate information. Potential approaches include automating much of the weather data collection and archiving in the United States, modernizing data archiving systems, improving the timeliness and variety of data and information to users, and making large research data sets more accessible at lower costs. Test studies have begun in the North Central region to transmit daily weather observations by touch-tone dialing. Agencies in the NCP are working together to develop other appropriate strategies to address these issues. In 1984, the NAS began a study of the climate data system in the United States and their report, due in 1985, will help define the direction of future actions.

CLIMATE IMPACTS AND POLICY

Milestones

- Transfer agroclimatic impact assessment procedures to LDCs
- Expand use of satellite data to detect crop stress and development

NOAA's Assessment and Information Services Center (AISC) has initiated a process model to transfer agroclimatic impact assessment procedures to lesser developed nations in Latin America, Southeast Asia, and Africa. This program, which is in various stages of implementation, is being accomplished with the help of the Agency for International Development, Office of Foreign Disaster Assistance, and the University of Missouri. Nine Southeast Asia countries, five Latin American-Caribbean countries, and four African countries have participated in the program so far. Training packages include a user's manual for microcomputer applications, development and interpretation of selected indices, and procedures to write agroclimatic impact assessments.

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Models of crop condition assessments that use basic rainfall data are being used operationally by the Assessment and Information Services Center to provide early warning on potential food shortages triggered by drought. In selected major production areas of developed countries, plant process growth and development models are being used with daily data to estimate crop yield for maize and wheat. The models are being used with NOAA satellite AVHRR data to detect crop stress and phenological development.

Carbon Dioxide and Trace Gases

Milestones

- Begin systematic monitoring of methane
- Prepare analysis of preindustrial levels of CO_2
- Reassess biological contribution to carbon cyle
- Provide initial assessment of CO_2—climate effect on water resources

Carbon dioxide-related research activities continue on a steady course. Anticipated milestones have been met and work is continuing on preparing major summaries of CO_2 research for publication in 1985. These "state-of-the-art" reports will present the most current and comprehensive statement possible of the knowns, unknowns, and uncertainties in all areas of CO_2 research.

NOAA, NSF, and DOE have effected a modest shift in research to give greater emphasis to other trace gases besides CO_2 because they have the potential for a serious effect on climate. Systematic monitoring of methane has begun and plans for expanding monitoring and research programs have been organized by NOAA and will be implemented in 1985. The Environmental Protection Agency (EPA) continues its assessment program of CO_2 effects and has published a new report on potential sea level rises (Barth and Titus, 1984). The EPA assessment program continues in 1985. The overall national effort to understand the potential CO_2 impact on global climate remains strong. Spending for the national programs on CO_2 exceeds $20 million per year among six agencies; more than $100 million has been spent since 1978.

CLIMATE RESEARCH AND PREDICTION

Ocean-Climate Studies

Milestones

- Develop implementation plans and project offices for TOGA and World Ocean Circulation Experiment (WOCE)

Major goals in 1984 have been to plan for initiation of TOGA and WOCE programs. TOGA formally began on January 1, 1985. Several years of extensive program development and planning have been necessary to organize ocean-wide climate observing systems. Although incomplete at this time, planning continues for international data management centers to receive and process TOGA data. An international planning conference on TOGA organized by WMO and ICSU was held in September 1984, and is the next step by WMO toward formalizing international commitments to TOGA. A national TOGA Project Office has been established in NOAA (TOGA Project Office, Office of Climate and Atmospheric Research, NOAA, 6010 Executive Blvd, Rockville, Md 20852) and an international TOGA project office has been established at NOAA/ERL—R/E3, 325 Broadway, Boulder, Col. 80303.

Progress on WOCE planning began with a workshop on "Global observation and understanding of the general circulation of the oceans" for some sixty oceanographers. The week-long workshop, which was organized by the NAS Board on Ocean Science and Policy, identified goals and objectives of the experiment and recommended that a U. S. planning committee be established to organize the program. A panel has been organized with support from the NSF and a planning office has been established at Texas A & M University.

Both TOGA and WOCE are major large-scale and expensive atmospheric and oceanic programs which will take place over the next 10 years. These and other programs, like the International Satellite Cloud Climatology Program (ISCCP), represent major new thrusts in atmospheric and ocean sciences. A growing number of large international programs are being suggested and/or organized and this represents a stress on resources and expertise to implement them. Clearly, the time is approaching for major advances in these areas. The availability of satellite technology is opening up new opportunities. The direction in the future seems to be toward larger research programs, and a review of these programs and priorities for the future will be considered at the time of the summer workshop (1985) to develop the second Five-Year NCP Plan.

Climate Prediction Research

Milestones

- Stimulate increased research efforts in ocean-atmospheric modeling
- Establish experimental forecast center to focus on El Nino-Southern Oscillation phenomena
- Expand joint industry-government partnership and organize a workshop on forecasting for industry

Extensive modeling experiments, summarized in the achievement section, are leading to increased optimism that

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improvements in forecast skill can be made on monthly and seasonal time scales.

A third experimental forecast center has been established at the University of Washington to focus on the prediction potential of El Nino-Southern Oscillation phenomena.

Credible long-range prediction capabilities would have obvious payoffs in benefits to many industrial endeavors. Recognizing this, several private companies have provided financial backing for this program. One of the aims of this collaboration between private industry and the federal government is to ensure the relevance of prediction research. As the program proceeds in developing prediction methods, those who would apply the first attempts at new predictions will understand how the outcome might be made more applicable. The first jointly sponsored project undertaken by the industry-government collaboration is led by Professor William Donn at Lamont-Doherty Geological Observatory in collaboration with The Analytical Sciences Corporation. This project will examine the performance and potential of a thermodynamic model in extended-range, monthly forecasting of climate variables.

Representatives of all three experimental climate forecast centers (Scripps Institution of Oceanography, NASA, and the University of Washington), the Climate Analysis Center, industry cosponsors of the program, and representatives of the climate research and industrial user communities participated in a climate prediction workshop in September 1984. The workshop explored present capabilities in climate prediction and current views of those capabilities from the perspective of private industry. Cosponsored by the American Meteorological Society and the NCPO, it permitted an exchange of views on potential applications (identifying the forecast products and formats most useful to private industry if they were available) and improvements in prediction information (products most likely to evolve from current research trends). A workshop report is planned for the *Bulletin of the American Meteorological Society* (1985). A summary of the workshop was published in the *Christian Science Monitor*, September 13, 1984.

Solar and Earth Radiation

Milestones

- Complete processing of ISCCP data
- Establish First ISCCP Regional Experiment (FIRE) project office
- Launch ERBE satellite

International Satellite Cloud Climatology Project (ISCCP)

The International Satellite Cloud Climatology project (ISCCP), the first project of the World Climate Research Program, completed its first operational year on June 30, 1984, collecting more than 90 percent of the data from six weather satellites. Preparations were completed this year to produce a reduced resolution version of all the data that have normalized radiances and a uniform format. This task is the responsibility of the ISCCP Global Processing Center located at Goddard Institute for Space Studies. Delivery of radiance data into the ISCCP central archive began in October 1984.

NOAA's NCDC produced and distributed the first edition of the ISCCP Catalog. The catalog describes the data and information that will be made available during the course of ISCCP and provides listings of the special ISCCP data sets produced from METEOSAT, GOES, and NOAA polar orbiter AVHRR data.

The Global Processing Center also prepares a cloud climatology from analysis of the radiance data. The first systematic comparison of cloud analysis methods was completed in FY 84, leading to design of a new hybrid algorithm for ISCCP. Three experimental, satellite-based cloud climatologies were produced at Langley Research Center, Goddard Space Flight Center and Goddard Institute for Space Studies, providing a solid basis for design and testing of the ISCCP algorithm. Preliminary testing of the ISCCP algorithm has been completed; first delivery of cloud data into the archive is anticipated in FY 85.

The ISCCP project began with the expectation of data from five geostationary satellites. The failure of GOES-5 and the changing location of GOES-6 have affected the spatial coverage of global cloud data received by processing centers. There has also been an absence of data from the Indian satellite. As a result, there have been readjustments in milestones and processing schedules. Despite these difficulties, the project continues and is providing global cloud data on 8-km by 8-km areas as derived from reflected solar radiation and emitted thermal radiation. Because cloudiness can vary substantially, even in an 8-km area, research is also under way to intercalibrate this global cloud measurement system with much higher spatial resolution data, such as that from Landsat.

Plans for the First ISCCP Regional Experiment continue and a project office has been established by NASA to organize scientific teams for this field project. The FIRE experiments will attempt to answer scientific questions on the formation, maintenance, and dissipation of radiatively important cloud types. The NASA, NOAA, NSF, and DOE will coordinate planning for FIRE.

Earth Radiation Budget Experiment (ERBE)

Earth Radiation Budget Experiment planning remains on schedule.

During the past year, fabrication and calibration of three sets of instruments for the Earth Radiation Budget Experiment were completed and the instruments were deliv-

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ered to the satellites which will place them in orbit. The first set of ERBE instruments was launched on the Shuttle on October 4, 1984, using the ERBS satellite in a lower 57° inclination orbit. The second set was launched on the NOAA F polar orbiting operational satellite in December 1984. The final set of ERBE instruments is expected to be launched on NOAA G in early FY 1986. Preliminary data from these instruments will be processed for initial scientific evaluation and investigation by the ERBE science team.

The ERBE ground data processing system, developed and implemented at NASA's Langley Research Center, has been completed in preparation for the launch. For ERBE science team investigations, the ERBE data products will be contained in the NASA Pilot Climate Data System. After complete quality control and validation, the ERBE data will be archived at the National Space Science Data Center/World Data Center A for Rockets and Satellites and at the National Climate Data Center.

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V. Summary of FY 1984-1986 Budget

The National Climate Program Act requires that the Office of Management and Budget (OMB) review all federal agencies' requests for climate activities as an integrated, coherent, multiagency budget. Accordingly, the National Climate Program Office (NCPO) compiles budget data from federal agencies prior to their submission to OMB and prepares an analysis of the budget in terms of base programs and initiatives. This analysis is reviewed and approved by the NCP Policy Board before submission to OMB.

The NCPO receives guidance from and provides assistance to the Climate Program Policy Board, consisting of federal agency representatives. The board is responsible for coordinated planning and progress review of the NCP, and for submitting a report to the OMB on agency budget requests. An interagency working group established by the board meets frequently to coordinate, plan, and help implement various climate-related activities.

The distribution of funding for climate research and services for FY 84, FY 85, and FY 86 is shown in table 1 for each agency. Table 2 gives more detail, showing the base program divided into the three major categories of the National Climate Program. Overall funding for the NCP has remained stable over the past several years.

Table 1
National Climate Program Budget Summary
FY 1984 to FY 1986 Agency Total Base Program
(million $)

	FY 84	FY 85[1]	FY 86[1]
Agriculture	$ 16.1	$ 16.1	16.1
Commerce	37.3	40.9	36.1
Defense	12.5	12.5	20.1
Energy	13.6	14.1	14.1
EPA	0.2	0.3	0.5
Interior	3.1	2.0	2.0
NASA	25.2	17.4	11.4
NSF	37.3	38.6	38.6
Total	$145.3	$141.9	$138.9

[1] Estimated totals.
[2] NCPO budget included each year at 1.1.
[3] Tentative totals.

Table 2

National Climate Program Budget Summary
FY 1984 to FY 1986 Base Program Cross-Cut
(million $)

	FY 84	FY 85[2]	FY 86[1]
Responding to Climate Impacts			
Agriculture	13.5	13.5	13.5
Commerce	3.9	1.9	1.9
Defense	–	–	–
Energy	12.5	11.8	11.7
EPA	0.2	0.3	0.5
Interior	1.3	0.6	0.6
NASA	–	–	–
NSF	6.4	0.9	0.9
Total	$37.8	29.0	29.1
Climate Research			
Agriculture	–	–	–
Commerce	21.1	23.8	20.5
Defense	2.0	2.0	2.1
Energy	–	0.8	0.8
EPA	–	–	–
Interior	0.9	0.8	0.8
NASA	24.6	16.7	10.7
NSF	29.7	37.7	37.7
Total	78.3	81.8	72.6
Providing Climate Products			
Agriculture	2.6	2.6	2.6
Commerce	11.2	14.1	12.6
Defense	10.5	10.5	18.0
Energy	1.1	1.5	1.6
EPA	–	–	–
Interior	0.9	0.6	0.6
NASA	0.6	0.7	0.7
NSF	1.2	–	–
Total	28.1	30.0	36.1

[1] Estimated totals.
[2] Tentative totals.

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APPENDIX

Reports Published in the World Climate Program Series

WCP-1—INFORMAL PLANNING MEETING ON WORLD CLIMATE PROGRAMME (FOOD) (GENEVA, 10-14 NOVEMBER 1980)

WCP-2—PRELIMINARY PLAN FOR THE WORLD CLIMATE RESEARCH PROGRAMME (GENEVA, JANUARY 1981)

WCP-3—JOINT WMO/ICSU/UNEP MEETING OF EXPERTS ON THE ASSESSMENT OF THE ROLE OF CO_2 ON CLIMATE VARIATIONS AND THEIR IMPACT (VILLACH, AUSTRIA, NOVEMBER 1980)

WCP-4—CONFERENCE STATEMENT AND PANEL REPORTS OF THE TECHNICAL CONFERENCE ON CLIMATE FOR ASIA AND THE WESTERN PACIFIC (GUANGZHOU, CHINA, 15-20 DECEMBER 1980) (out of print: has been incorporated into the Report of the Conference which has been published as WMO Publication No. 578)

WCP-5—INFORMAL PLANNING MEETING ON WORLD CLIMATE PROGRAMME—WATER (GENEVA, 2-6 FEBRUARY 1981) (out of print)

WCP-6—THE INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT (GENEVA, JANUARY 1981) (out of print)

WCP-7—REPORT OF THE THIRD MEETING OF THE JSC WORKING GROUP ON HYDROLOGY AND LAND SURFACE PROCESSES (COLLEGE PARK, MARYLAND, USA, 10 JANUARY 1981) (out of print)

WCP-8—REPORT OF THE MEETING OF THE COORDINATION OF PLANS FOR FUTURE SATELLITE OBSERVING SYSTEMS AND OCEAN EXPERIMENTS TO BE ORGANIZED WITHIN THE WCRP (CHILTON, U.K., 26-31 JANUARY 1981) (out of print)

WCP-9—SUMMARY REPORT OF THE INFORMAL PLANNING MEETING ON THE WEST AFRICAN DATA BANK (GENEVA, 25-27 FEBRUARY 1981) (out of print)

WCP-10—MEETING OF SELECTED EXPERTS ON CLIMATE-RELATED MONITORING (GENEVA, 21-24 APRIL 1981)

WCP-11—JSC/CCCO MEETING ON TIME SERIES OF OCEAN MEASUREMENTS (TOKYO, 11-15 MAY 1981) (out of print)

WCP-12—MEETING OF JSC EXPERTS ON AEROSOLS AND CLIMATE (GENEVA, 27-31 OCTOBER 1980

WCP-13—PLAN FOR WCP DEMONSTRATION PROJECTS—FOOD, ARISING FROM INFORMAL FAO/WMO MEETING OF EXPERTS (GENEVA, 27-31 JULY 1981)

WCP-14—PAPERS PRESENTED AT THE WMO/ICSU/UNEP SCIENTIFIC CONFERENCE ON ANALYSIS AND INTERPRETATION OF ATMOSPHERIC CO_2 DATA (BERN, 14-18 SEPTEMBER 1981) (out of print)

WCP-15—REPORT OF THE INFORMAL PLANNING MEETING ON WCP DATA REFERRAL SYSTEM (GENEVA, 28 SEPTEMBER-2 OCTOBER 1981) (out of print)

WCP-16—REPORT OF THE INFORMAL PLANNING MEETING ON WCP ENERGY (ROSKILDE, 1-3 DECEMBER 1981)

WCP-17—REPORT OF THE WCP DATA MANAGEMENT MEETING (GENEVA, 16-20 NOVEMBER 1981) (out of print)

WCP-18—EXTENDED CLOUDS AND RADIATION, BY C.M.R. PLATT, AUSTRALIA. A REPORT COMPILED FOR THE INTERNATIONAL RADIATION COMMISSION AND PRESENTED AT IAMAP (HAMBURG, AUGUST 1981)

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WCP-19—PLANNING GUIDANCE FOR THE WORLD CLIMATE DATA SYSTEM, BY R.L. JENNE (USA, FEBRUARY 1982)

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